ILLUMINATING ENGINEERING

FEBRUARY, 1950

Effect of Source Size on Approach Light Performance
I.E.S. Recommended Practice of Daylighting
Technique of Lighting Generating Stations
Modernization of a Department Store
Remodeling with Light and Color
Troffer Lighted Classrooms
Office Lighting for Comfort

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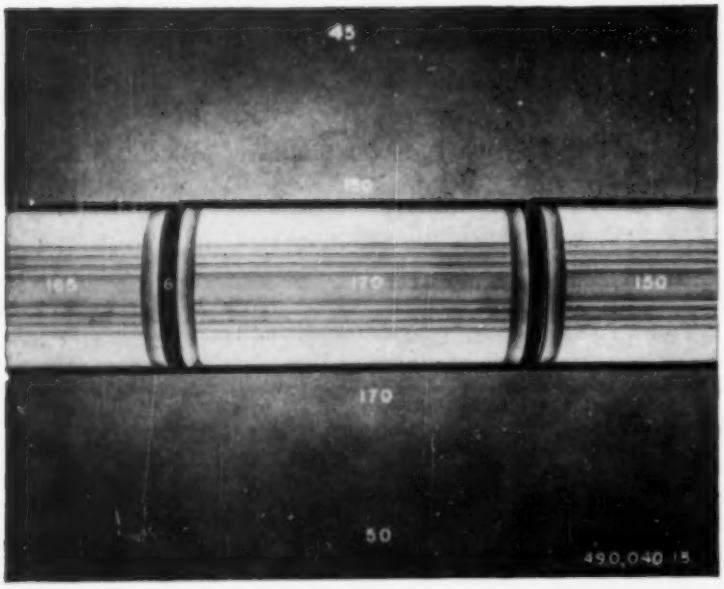

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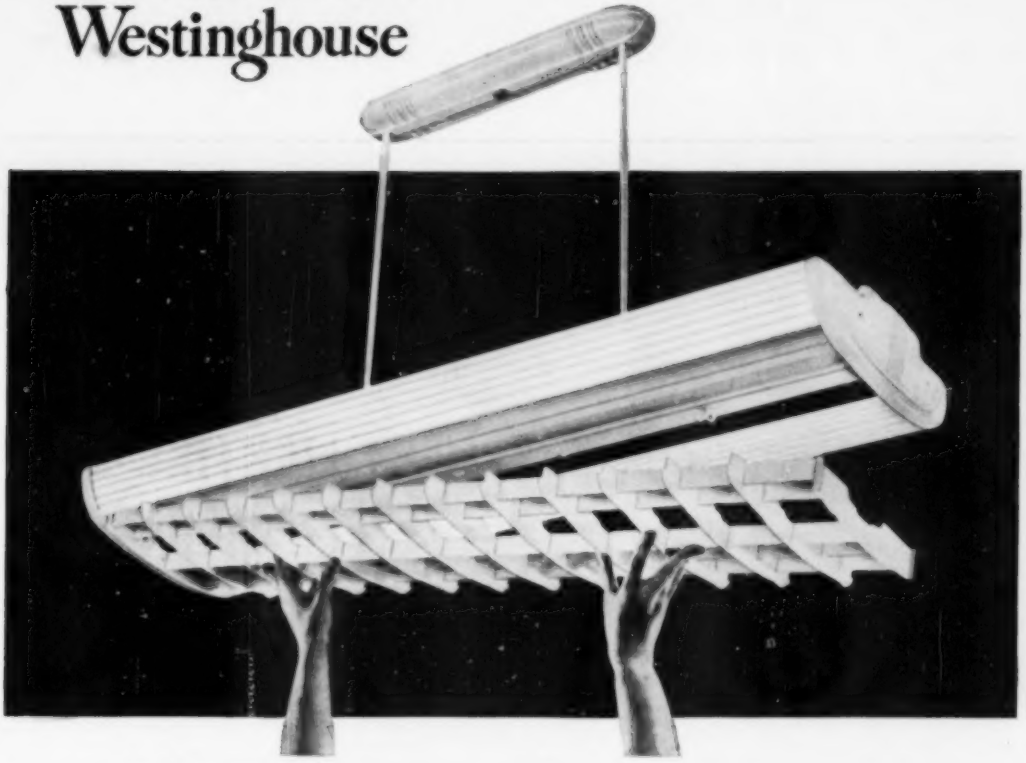

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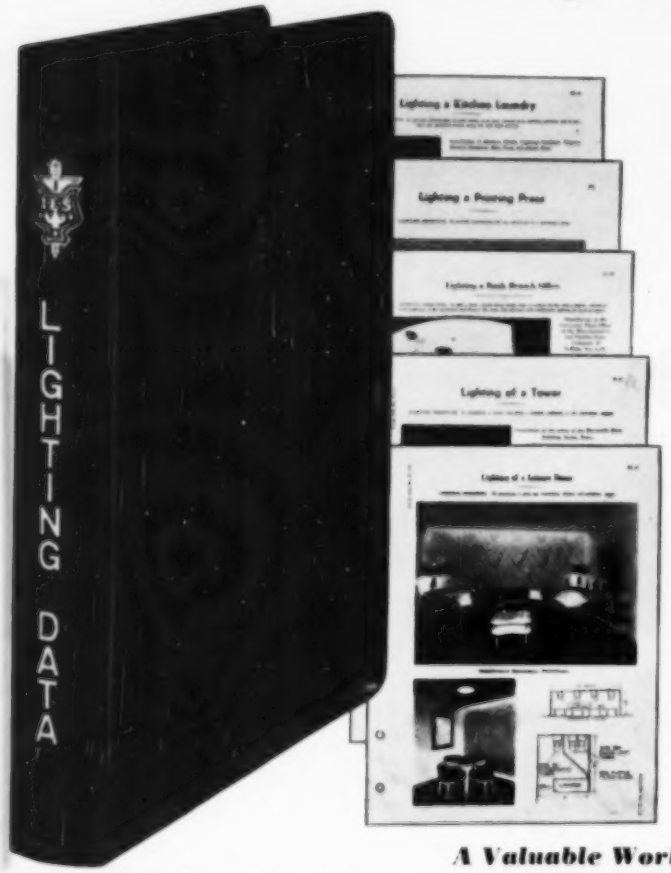

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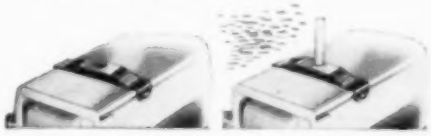

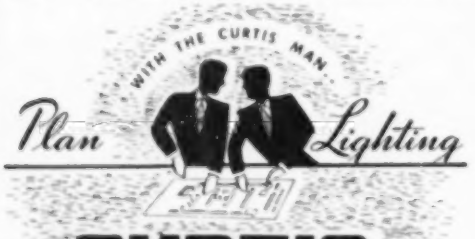

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One-Hundred Footcandles in Troffer Lighted Classrooms

By D. E. MOZES
T. R. ANDERSON

MANY approaches to the problem of adequate and proper lighting of classrooms are based on levels of 30 to 40 footcandles. In the design and application of troffer lighting for the classrooms of two school buildings in Coulee Dam, Washington, discussed here, levels approaching 100 footcandles were not considered excessive, particularly if the resulting brightnesses are within proper limits.

The two school buildings involved are the Columbia School, originally built in 1935, and the Central School built in 1946. Both school buildings were constructed by the Bureau of Reclamation. Troffer lighting of the higher intensity, was initially considered for only the Central School until, late in the spring of 1947, the Columbia School suffered partial destruction by fire attributable to a schoolboy arsonist. At the time of this fire, designs for the troffer lighting in the Central School were in progress, and it was necessary to divert design efforts to the reconstruction of the Columbia School prior to commencement of the fall school term. Application of troffers was not new at Coulee Dam, as the lighting system for a four-classroom addition to the Columbia School building in 1941, was comprised of one-lamp fluorescent open reflectors in continuous rows. Troffer lighting of the higher intensity was incorporated in the rebuilt Columbia School as well as the New Central School.

The ceilings in both schools are finished with 12-in-h-square acoustical tile which has a reflection factor of about 78 per cent. The upper portions of the walls are painted in an off-white color with a reflection factor of about 83 per cent. The slate chalk boards have a reflection factor of 8 per cent, and the desks, tan in color, 20 per cent. In the

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949 at French Lick, Indiana. Mr. Mozes is Lighting Specialist, General Electric Supply Corporation, Spokane, Washington. Mr. Anderson is Electrical Engineer, Columbia Basin Project, Bureau of Reclamation, Coulee Dam, Washington. All photos, Columbia Basin Project, Grand Coulee Dam.

Figure 1a. (Right) Classroom in Columbia School, showing the recessed fluorescent lighting. Figure 1b. (Left) A typical plan view of the fluorescent lighting in the classrooms of the Columbia School. Fixtures are 2-lamp, 40-watt, troffer, Miller "Ceilings Unlimited." Power supply, 3-phase, 120/208 volts. Letter on each fixture denotes phase to which it is connected.

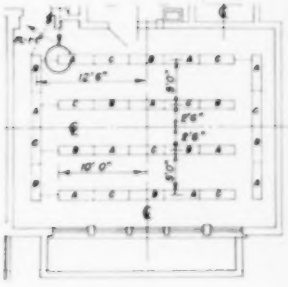


Figure 2a. (Above) Classroom in Central School, showing the recessed fluorescent lighting.

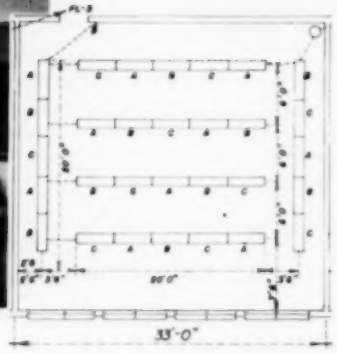


Figure 2b. (Below) A typical plan view of the fluorescent lighting in the classrooms of the Central School. Fixtures are 2-lamp, 40-watt, troffer, Miller "Ceilings Unlimited." Power supply, 3-phase, 120/208 volts. Letter on each figure denotes phase to which it is connected.

Columbia School the floors are natural finished hardwood with a reflection factor of 30 per cent. The Central School floors are laid with a large checkerboard pattern linoleum with a reflection factor of about 20 per cent. The chalk boards, desks, and floors could have been finished with lighter colors, but scarcity of materials at that time limited the choice.

The rooms in the Columbia School are 22 feet by 29 feet with 11-foot-5-inch ceiling. The Central School rooms are 33 feet by 30 feet 9 inches, with 11-foot-5-inch ceilings. In the classrooms of both schools the scheme is the same; that is, there are four continuous rows of two-lamp 40-watt fluorescent troffers with an additional row at front and rear parallel to the chalk boards, to give better vertical illumination on the boards. Fluorescent lamps, 4500° white 40-watt were used in the troffers. The troffers have white enamel steel reflectors with hinged door frames for every 4-foot section. Four clear prismatic lenses, providing extensive distribution, are held in each frame.

The troffer installations in the Central School rooms are in 20-foot continuous rows, each made up of two 8-foot sections and a 4-foot extension. The Columbia School installations are the same except for the front and rear rows, which are only 16 feet long. The equipment requires supports only at the ends and the junction points. This means that supports in almost all cases are 8 feet apart. In addition, the furring hangers are the type capable of supporting both the suspended ceiling and the troffers.

The layout in the Columbia School rooms is symmetrical with respect to the distance from the outside rows to the walls and windows; but in the Central School rooms the arrangement, although symmetrical, is offset 3 feet from the windows so that full advantage may be taken of day lighting. Another design difference in the lighting of the two buildings is that the spacing of the rows in the Columbia School rooms is 5 feet on centers as compared with 6 feet in the Central School.

The wiring of the troffers takes advantage of the 3-phase 4-wire power supply, in that adjacent 4-foot units are supplied by a different phase. Switching of rows is arranged so that inside rows alone can be used when desired. All windows have double roller light tan shades which roll down from the top. They seem to do a satisfactory job of subduing sky brightness.

Light measurements were taken in the classroom in the southeast portion of the Columbia School, and in one of the classrooms on the north side of

the Central School. Initial footcandle measurements in the Columbia School classroom varied from 90 to 125, and in the Central School classroom, from 80 to 104. After a year of operation footcandle levels have depreciated to from 65 in the right front corner to 105 under the row next to the windows in the Columbia School classroom, in which readings were taken with all blinds down, at 11:00 A.M., February 24, 1949 when the weather was cloudy. Depreciated readings in the Central School classroom vary from 65 in the far corner to 120 under the first row next to the window. These measurements were taken the same day at 2:00 in the afternoon. It was still cloudy but only the top section of the blinds was drawn. Vertical readings at the chalk boards averaged 30 footcandles.

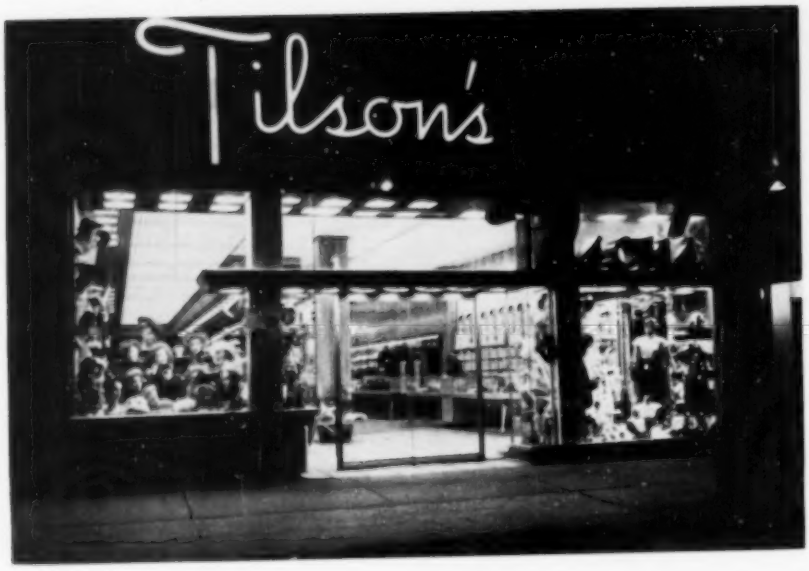
Brightness measurements were made in the Columbia School classroom from the second row rear seat. The troffer lenses varied from 230 footlamberts on the troffer overhead at about 45°, to 140 footlamberts on the front row parallel to the chalk board. The ceiling tiles adjacent to the rows of lenses ranged from 40 to 16 footlamberts. These are ratios varying from approximately 5½ to 1 to about 9 to 1, and compare favorably with the American Standard Practice for School Lighting recommendations of 20 to 1. The American Standard Practice recommends a ratio of 1 to 10 between desk and ceiling. We found that there were from 70 to 92 footlamberts on white paper on the desks which compared to the brightest surface on the ceiling, 140 to 230 footlamberts, resulted in ratios of 1 to 2 and 1 to 2½ which are also well within American Standard Practice recommendations. The brightness ratio between desk and floor averaged 1 to 1/5; for example, 92 footlamberts on the task to 19 on the floor. The American Standard Practice limit is 1 to 1/10.

The desk tops are several shades darker than the desired finish, and our measurements of the ratio between the task and desk top did not quite "make the grade." The recommended ratio is 1 to ⅓ and 92 footlamberts on task to 26 footlamberts on desk is a ratio of approximately 1 to ¼.

The hall in the Central School is lighted by 4-foot sections spaced 12 feet apart using the same type of troffers as those installed in the classrooms.

The Columbia School gymnasium was re-lighted after the fire with twenty 1000-watt prismatic refractors which deliver 40 footcandles in corners to 57 in the center of the floor. Disconnect and lowering hangers serviced from the balcony make maintenance easy. Brightness at the fixture overhead at 45° is 110 footlamberts which compares very favorably with 11 footlamberts on the ceilings.

Figure 3. (Above) Auditorium in Columbia School, showing the incandescent lighting fixtures with disconnect and lowering hangers. Figure 4. (Right) Hallway in Central School, showing the recessed fluorescent lighting.



Remodeling — With Light and Color

TILSON'S, a ladies apparel store located on Detroit's busiest block, reopened last Spring after a complete remodeling program. A saunter through this modern shop demonstrates at a glance what warmth and comfort may be wrought by color and light. Designed by Maxwell E. Wright, Pontiac, Michigan architect, in cooperation with the Detroit Edison Company, the planned lighting for the store employs examples of almost every type of lighting design—louverall ceilings—cove lighting—down lighting—accent, silhouette sections and case lighting.

As shown by the picture at the top of the page, the outside view shows an inviting interior. On the upper level of the window, units using 300-watt lamps are on approximately two-foot centers, with the same using 200-watt lamps spaced 18 feet apart on the lower level. The large sign uses neon tubing with a plastic face, while the other sign is a silhouette sign with the light from the window to set it off.

Below, and on the facing page, may be seen some of the various types of lighting used. The louverall ceiling is below a cavity $3\frac{1}{2}$ feet deep. Slimline lamps of 42-, 72- and 96-inch lengths operating at

Information and photographs supplied by Herbert J. Miller, Detroit Edison Co., Detroit, Michigan

200 ma, are on 12-foot centers, 12 inches above the louverall. To hide a number of unsightly pipes and part of the sprinkler system, the cavity above the louverall was painted black on the architect's recommendation.

Drop ceilings, another modern note, use 300-watt incandescent lamps on 3½- to 4-foot centers—contrasting effectively with the fluorescent lighting.

To highlight the merchandise displayed in wall niches, flexible units are suspended from the ceiling about three feet apart, using 150-watt reflector floods. The wall cases have their own lighting, however — standard strips with 20- and 40-watt fluorescent lamps. The interior of the cases has been painted a chartreuse color, highlighting them additionally against the California Redwood of the paneled walls.

Another lighting design employed is visible in the view of the handbag department shown below. At the right of the picture, a wall case may be noted, using a 40-watt fluorescent channel. In the picture the light source is noticeable by the reflection in the mirror at the back of the case. Slimlines are used here, of 42-inch and 62-inch size.

Opposite this area is the millinery department, with costume jewelry counters running through the center of the area (lower photo, facing page). This is a good view of the drop ceiling with its cove of cold cathode tubing operating on a 12,000-volt series circuit. In this view is also apparent the extensive use of mirrors throughout the store. The columns are all mirrored down the center and reflect part of the silhouette sign on the outside. Recessed units in the center area are over the individual tables where the customer tries on the hats.

Wall lighting in the millinery department is produced by 20- and 40-watt fluorescent tubes down each side of the splayde oak paneling, with the niches painted yellow. As with display niches elsewhere in the store, the merchandise is also highlighted by 150-watt reflector floods in suspended flexible units.

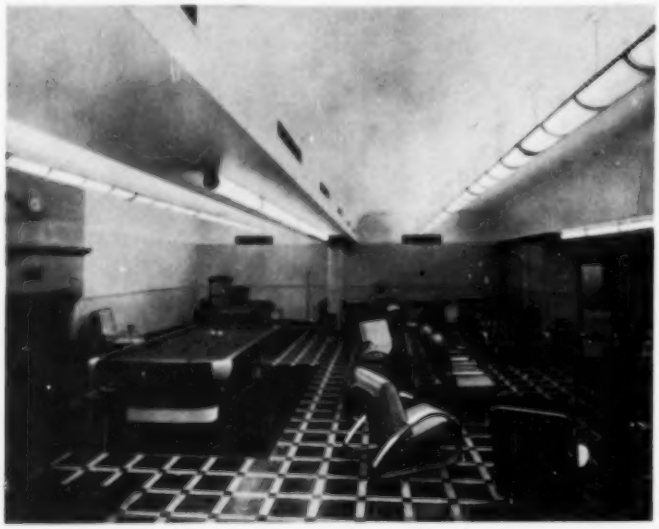
In the hosiery bar, part of which is shown below, twelve plaster niches, each using a 150-watt reflector lamp, highlight the color and sheerness of the hose displayed.

The owner of the store has evidenced considerable enthusiasm for its lighting — claiming increased sales, and greatly improved use of space.

What was once a millinery store has been converted into a ladies specialty shop having several departments. A number of types of lighting design have been employed, including louverall ceilings, drop ceilings, coves, and recessed units — utilizing effectively incandescent and both hot and cold cathode light sources.

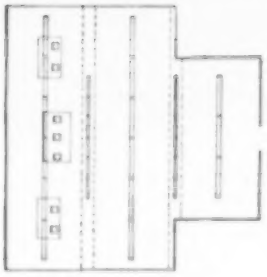
Lighting a Recreation Room

LIGHTING OBJECTIVE: To provide illumination for reading, card playing, pool and billiards.



Installation at
American Federation of Musicians' Union
Local No. 6
230 Jones Street
San Francisco, California

General Information: The area is approximately 49 x 52 x 12, less two 10-foot x 16-foot corners. (See drawing.) There are two beams three feet wide and four feet deep spaced 17 feet apart. Surface characteristics of the area are indicated below:



ceiling	white	66% RF
walls	green	50% RF
dado	green	43% RF
floor	red-brown Linoleum	11% RF
billiard and pool table tops	green	8% RF

Installation: General illumination is provided by fifteen Wakefield "Star" (No. STA-200 ma) luminaires each containing four 96-inch, 51 watt, 3500K slimline fluorescent lamps mounted 10 feet above the floor; and twelve Wiremold No. 25H14 semi-indirect units each with one 48-inch, 40-watt 3500K fluorescent lamp mounted on the lower surfaces of the beams. Supplementary lighting on pool and billiard tables is supplied by seven semi-recessed Holophane "Counter-lite" (No. F 1814) units containing 200-watt PS-30 incandescent lamps.

Horizontal illumination maintained in service is 30 footcandles in reading area (30 inches above floor) and 56 to 59 footcandles on billiard and pool tables. Brightnesses are indicated below:

Ceiling			Luminaires		
center of room		18.6 footlamberts	Wakefield		
above Wakefield luminaire		140 " "	90° to side	126 footlamberts	
Side of Beam		19.6 " "	90° to bottom	60 " "	
End Wall		150 " "	45° (crosswise) to bottom	120 " "	
Dado		92 " "	Wiremold		
Floor	(average)	10 " "	90° to bottom	400 " "	
Fireplace (90°)		12.5 " "	45° to side	400 " "	
Billiard Table Top (45°)		6 " "			

Lighting data submitted by Warren W. Weiss, Pacific Gas and Electric Company, San Francisco, California as an illustration of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31/17

Technique of Lighting Generating Stations

By H. F. CARROLL
W. B. MORTON

THE LIGHTING of a modern generating station presents many problems not generally encountered in other industrial lighting situations. In a generating station the conditions are so different from conventional lighting projects, that in many cases only empirical formulas and long years of experience can prescribe the lighting installation that is best suited to this particular type of problem.

This was pointed out by Brainerd and Salneu in their paper on generating station lighting, presented to this society at the 1947 Technical Conference in New Orleans.[1] As emphasized by these authors, steam electric generating stations are characterized by irregular areas and ceilings that are obstructed with pipes, conduits, wire and cable troughs and a variation of high and low ceilings. Some of these areas contain machinery and equipment that do not conform to any symmetrical pattern and leave little space for optimum locations of desired lighting equipment. Although not brought out by Brainerd and Salneu, there is also the very important factor of the human element entering into the design of generating station lighting. Operators in these stations lay strong emphasis on such things as visual acuity and elimination of reflected glare, brightness and brightness differences.

It is highly gratifying to note that illuminating engineers are beginning to take keen interest in generating station lighting. It is also highly gratifying to realize that the efforts of a few pioneers in the past 15 years have been able to produce snowball results and arouse interest of not only the illuminating engineers but the power design engineers as well, in this major problem.[2] Management, too, recognizes that the lighting of a generating station is a very important engineering function, and is well worth the necessary expenditure to provide adequate seeing for the operating personnel, and in addition to afford the utility an opportunity to demonstrate to its customers who visit the property, how commercial plants should be lighted. The relative cost of providing adequate lighting in a generating station is not excessive, possibly amounting to one-quarter to one-half per cent of the project cost.

The authors of this paper are presenting a design of generating station lighting, that of the new Sunbury Plant of Pennsylvania Power & Light Co., which they hope will contribute to this phase of lighting, in which interest is once more being aroused. It is hoped that this contribution will awaken further thinking in connection with this problem and stimulate others to present their views and to describe their experiences and developments in this connection. The recent formation of an Illuminating Engineering Society Committee on Lighting of Central Station Properties is a forward step from which a worthwhile contribution is expected to result.

The Problem at Sunbury

The Sunbury Steam Electric Station, located on the Susquehanna River in Central Eastern Pennsylvania, comprises an ultimate development of six turbo-generator units, totaling 550,000 kilowatts. In physical scope, the initial project covers a plot of ground over two miles long and one-quarter of a mile wide (Fig. 1). This plot is divided into three general areas: a million-ton coal storage, handling and reclaiming area, the general operating area, and the ash disposal area. In addition to the main plant building rising 300 feet to the top of the stacks, there are nine miles of railroad trackage, four miles of paved roadways, two large high-voltage substations, a mile of coal conveying and handling runways, in addition to seventeen outlying buildings consisting of screen house, water treatment building, a car dumper with a pit of several elevations to a depth of 65 feet below grade, coal handling and processing equipment buildings and structures, large building for thawing trains of loaded coal cars, locomotive repair building, a substation control building, a large office and service building, scale house and gate house.

The initial installation has two turbo-generator units of 75,000 kw capacity each with four 400,000

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Authors: Pennsylvania Power and Light Co., Allentown, Pa.

Figure 1. Air view of the Sunbury Steam Electric Station project during construction progress, showing the magnitude of the lighting problem. Only the operating and coal storage areas appear in this view. The Quonset hut structures are temporary construction buildings.

lb per hour pulverized fuel burning steam generators, the largest in the world designed for burning anthracite, installed in the main plant building covering nearly two acres, the boiler house of which has eleven elevations above grade. The turbine room and auxiliary bay areas have fewer elevations than the boiler house but present a variety of lighting problems. The most important areas in these buildings are the two centralized control rooms, the nerve centers of the plant, where operators are stationed continuously three shifts per day and from where nearly all plant operations are controlled.

Requirements

The basic requirements established for the lighting of the project were simple requisites of good lighting in conformity with the modern conception of the illumination necessary for the task, and for human comfort. In adherence to these principles, efforts were made to eliminate disturbing brightnesses, brightness differences, annoying color contrasts, bothersome reflections, and the "cavern" effect created by looking up to mezzanine galleries into bright sources of light against dark backgrounds. Areas with grating flooring or ceilings were to be illuminated so there would be no bright light sources below the gratings and minimum of glare from all overhead sources. In control rooms reflected images in instruments were to be minimized or eliminated and in offices comfort was of prime importance.

Intensities adequate for all classes of work were established. The general intensity throughout the station was designed for 25 footcandles, except for 15 footcandles minimum in walkways, stairways, passages, etc. In control rooms, low brightnesses and vertical intensities on instruments of 40-50 footcandles were specified, which resulted in 115 to 125 footcandles horizontal illumination. A value of 50 footcandles was specified for the turbine room area.

The design has made use of fluorescent lighting where it would apply, and it is estimated that fluorescent tubes are used in about 30 per cent of the areas about the plant.

In all designs of offices, control rooms, laboratories, and such spaces where personnel are stationed continuously, the health and comfort of the personnel were predominant in the selection of pleasing colors, providing air conditioning, high intensity glareless illumination and glass block wall panels for maximum admission of daylight.

Throughout the plant, particularly in boiler and turbine rooms, supply circuits were required to be so interspersed that the failure of any power source would not result in the loss of more than 50 per cent of the illumination in any one area.

Painting

Throughout the station special care was given to the painting problem. In all areas, efforts were made to avoid dark surfaces. Both exterior and interior of partition walls in the plant are of a light green tile. Equipment throughout was painted some form of light green, light gray, or a light buff color except where items such as turbine room crane are painted a "caution" yellow for safety or other reasons. Floor tile is a quarry red except for control room where the tile is a light marble color.

Use of Model

A scale model (Fig. 2), was constructed during early design stages with all details of boiler, auxiliary, and turbine areas faithfully reproduced in detail. Although this model was built for general design purposes to obtain the best in design of plant and equipment, for use in instructing operators and for the education of employees and others interested, it proved to be invaluable in the laying out of the lighting for these buildings. The exact reproduction of the finished boiler house and turbine room with all equipment located to scale (Fig. 3) permitted complete visualization of each lighting design before the designs were finally drawn up. This utilization is a strong argument in itself for the construction of a scale model during design of the plant.

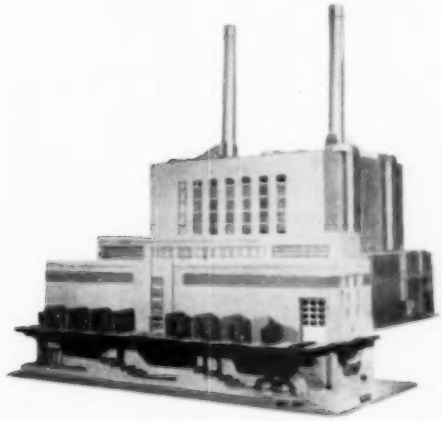

Figure 2. Use of a scale model materially aided in visualizing results from design plans as engineering progressed.

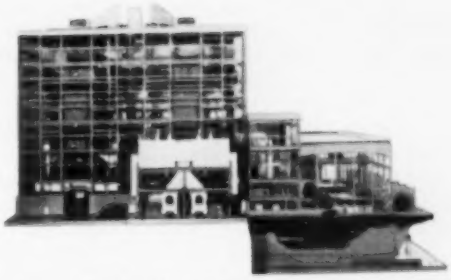

Figure 3. Construction of model permitted "splitting" into sections providing complete visibility of interior areas.

Control Rooms

The control rooms are the nerve centers of the plant, where nearly all major plant operations are controlled. The lighting of the control room is a very highly specialized type of problem. As all station designers know, the design of adequate switchboard and control room illumination has for many years presented three major problems to the design engineer.[3, 4] First, what in older stations is the most frequent cause of eyestrain complaint, the sharp contrast between light ceiling or sources of light, and the dark surfaces such as old fashioned black switchboards, improper window shades, high dados, etc., and second, direct glare from open light sources (including daylight) within the operator's field of vision, and third, specular reflection, and reflected contrasting images or highlights in the instrument faces that interfere with reading of the instrument scales.

The first problem, that of contrast between light and dark surfaces can, of course, be readily disposed of by carefully painting all surfaces some shade of light color, even including such things as machinery and battery racks, if such are located in the control room. The second problem is easily solved so far as direct glare in the operator's field of vision is concerned as there are now many new designs of lighting units available that will accomplish this, but some of these aggravate the third problem, that of highlights and reflected contrasting brightnesses in the instrument faces. If windows cannot be eliminated in the design, modern blinds can usually be resorted to for protection against the daylight glare source.

The third problem, light reflection in instruments, is the one we are concerned with most and is the one most difficult to overcome.

Any source of light for switchboard illumination will be reflected in the glass faces of the switchboard instruments. If this is a direct source, location of the fixtures at an angle of incidence so that the light reflection is out of the operator's field of vision overcomes the problem of instrument glare. However, placing the light source close to the vertical face of the board to obtain satisfactory angle of incidence will in many cases produce undesirable shadows on the instrument scales and reduce visibility of switchboard nameplates. Shadow on the scales could be completely eliminated if instrument manufacturers would build instruments with complete glass cases. Some engineers have even altered standard instruments to provide these glass covers.

Some instrument manufacturers will furnish the so-called non-glare glass to eliminate reflections, but in most instances these have not been entirely satisfactory. In some cases scales on the instruments have become fuzzy and indistinct in a few years. We recognize the study that has been given to this problem by manufacturers of prismatic equipment and by other utility and illuminating engineers. We have used and are planning to use for certain applications, the prismatic lens units available for obtaining high intensity lighting on the switchboard from sources placed so as to avoid objectionable reflection from the light source. However, the problem of reflection is accentuated by switchboard arrangements such as at Sunbury which (ultimately) wall in the operator, and the direct lights placed to eliminate glare on one switchboard may cause intolerable reflection on adjacent boards.

The problem of reflection can be reduced materially by the totally indirect type of lighting installation where fixtures can be placed out of the field of reflection such as behind switchboards, provided room proportions are favorable. The indirect system, however, is in general limited to relatively low footcandle intensity (probably 25 footcandles). The engineer then must turn to the artificial skylight or some reasonable facsimile to obtain higher intensities of light with minimum brightnesses, brightness ratio and brightness variation. Now, it is a fact that if the brightness on the glass instrument front is of even intensity, that is, without a break, such as would be obtained from a solid white ceiling used as a light source, and the intensity of the brightness reflection in the glass is not much greater than the intensity on the instrument scale behind the glass, the highlight will then be mitigated to a degree that no interference with reading of scales will result.

The control room lighting problem at Sunbury involved two rooms. One, the plant centralized control room for control of both turbines and boilers, which is a room approximately 50 ft by 40 ft laid out with control boards in a complete square about the operator. The second room is a control room in the outdoor substation control house. This room is 60 ft by 50 ft and contains all switchboard control, relay, and carrier current panels for the two 66 kv switchyards provided with the initial 150,000 kw installation, and for the future 220 kv switchyard. The problem is similar for each room with a 15 ft ceiling and switchboards ultimately on four sides. These switchboards are finished in opalescent gray aluminum lacquer as are all of the 75 other switchboards located throughout the plant. Each control room is finished in light green wall tile with marbleized rubber tile floor.

During early design, a mock control room with switchboard panels and instruments was set up, based on a layout having a continuous row of three 40-watt fluorescent fixtures located about three feet from each switchboard face with supplementary units in the center area between. Actual tests showed that even with these fixtures tilted and louvered, or with a stepped false ceiling, it was impossible to avoid appearance of images from the fixtures on the faces of all the instruments located 90° to the row of lights. These made reading of scales very difficult.

Investigation of the possibilities of a louvered

Figure 4. Portion of substation control room with louver-all ceiling during construction. Note even intensity on boards with absence of glare.

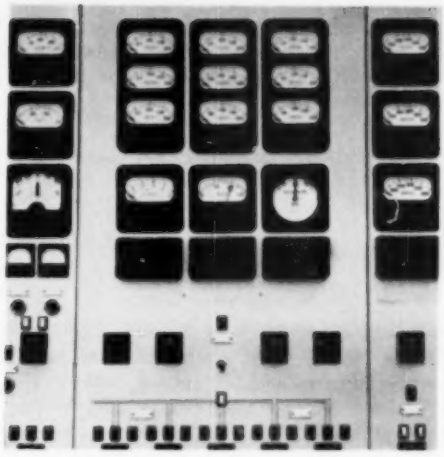

Figure 5. Close-up of instruments shows lack of glare and objectionable brightness differences in instrument faces.

ceiling based on a complete suspended ceiling of egg-crate louver construction from wall to wall with lighting units closely spaced above the ceiling to obtain desired intensities, indicated that this type of construction would provide the needed artificial skylight type of illumination (Fig. 4).

Although this louvered ceiling type of illumination had been successfully used in a number of stores and offices, at that time, so far as could be learned, it had not been seriously considered by anyone for control room applications. In order to determine whether any objectionable highlights would exist, a mock switchboard panel was set up in the office of one of the louver manufacturers where a plastic louver type ceiling had been installed. Careful checking of this mock panel indicated that although some minor highlight existed in the faces of the top instrument, it was not at all objectionable and the scales were still entirely readable. In the actual installation at Sunbury, no objectionable reflection whatever exists from the louvered ceiling, with full intensity of illumination (Fig. 5).

The louvered ceiling design selected consists of 3 ft x 5 ft sections of 2" x 2" x 2" vinylite egg-crate mounted 11 feet above the floor with a three-lamp 40-watt fluorescent porcelain enameled reflector mounted two feet above the louver ceiling over each 3 ft x 5 ft section of louver (Fig. 6).

The installation results in an even level of illumination with minimum brightness effect in instruments from overhead light sources. Average illumination obtained was 50 footcandles on the vertical faces of the switchboards with 115 to 125 maintained footcandles on horizontal surfaces, with a brightness within a 4 to 1 ratio. Circuiting and switching provides for operation of one, two, or three tubes in each fixture as desired. Switching out one tube will reduce the illumination to about 85 footcandles, and switching out two tubes will reduce this to about 45 footcandles.

The ceiling and all piping, conduit, air ducts, etc. above the louver ceiling are painted white to obtain maximum light reflection, maintain cleanli-

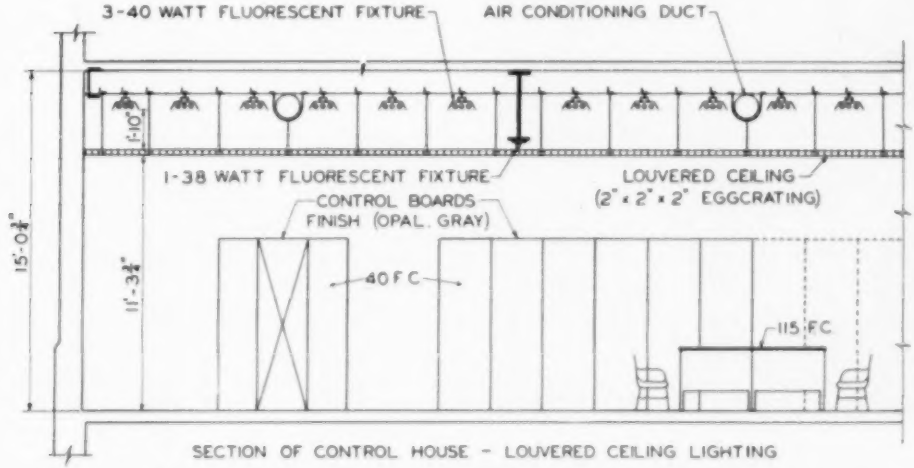

Figure 6. Details of louverall ceiling design and location of luminaires and equipment above the ceiling.

ness, and to facilitate maintenance of lighting and equipment above the ceiling. It was first thought that the louver ceiling would have acoustical properties but the manufacturer states that the material is acoustically neutral and has little effect on the acoustics of a room. The footcandle levels with use of plastic louvers are about 20 per cent higher than obtained with etched aluminum and about 60 per cent higher than matte white steel louvers. The louver ceiling acts as a diffuser for air-conditioning ducts which discharge cool air in summer and warm air in winter above the ceiling.

It is sometimes pointed out that the louver ceiling illumination has the disadvantage of excessive glint reflection on horizontal surfaces. This was recognized, but the major factor in the control room lighting was vertical illumination of switchboards and this disadvantage was of secondary importance.

Consideration was given to possibilities of a luminous ceiling of translucent sheet plastic which has been used successfully in one utility's plant. However, there are inherent disadvantages to this type ceiling that appeared to offset its advantages. The plastic sheet ceiling is limited to relatively low intensities in the order of 30-40 footcandles. It complicates the air conditioning system design, the sheets must be wax treated to prevent electrostatic charge that collects dust and it was believed they would involve a greater maintenance problem.

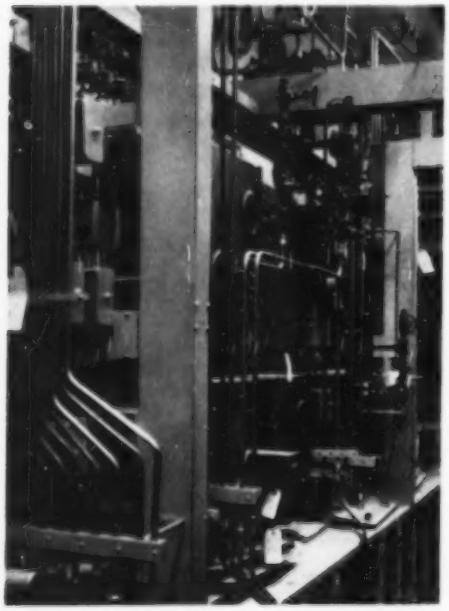

Figure 7. Interior of switchboard cubicle in main control room lighted by continuous row of two 40-watt fluorescent units with 360° coverage.

The inside of the switchboard cubicles is illuminated from a continuous row of two 40-watt fluorescent units providing good working intensity on back of switchboards with nearly 360° coverage. (Fig. 7).

Auxiliary Control Boards

In addition to the two major control rooms, there are located about the plant 75 local switchboards which ordinarily would present the usual switchboard lighting problem. It was felt, however, that in the case of these local boards, no subsidiary source of illumination would need to be applied, since 25 footcandles of general illumination is provided. It is true that at these local switchboards there will be some direct reflection experienced in the instruments, but since these local stations are only intermittently operated, it is not felt that this problem will be serious. If, after the plant has been placed in "full commercial operation," any one of these specific locations indicates unsatisfactory lighting results, it can be handled as a separate problem.

Turbine Room

The turbine room, which is 66 ft by 280 ft, is lighted with a 1:1 lumen ratio of combination incandescent-mercury lighting, using two 400-watt 16,000 lumen mercury lamps and one 1500-watt, 33,000 lumen incandescent lamp per outlet, mounted in three rows, on 23-ft by 24-ft centers at a 50-ft mounting height. The luminaires are serviced from the crane and are mounted on a channel bracket (Fig. 8), which was fabricated on the job. Consideration was given to the use of roof boxes that would permit servicing from the roof, but the possibility of water leakage was felt to be too great to justify this design.

The rows of lights are controlled separately by contactors operated from switches at the control room on the turbine room floor elevation. Here, as in other locations in the plant, it was decided to provide ceiling illumination in order to reduce brightness contrasts and to show the architectural appearance of the ceiling to advantage. To provide for this, prismatic glass luminaires are used. The backing was left off the glass mercury units, but retained on the incandescent units because of the high heat generated from the 1500-watt lamps. The removal of the metal backing from the mer-

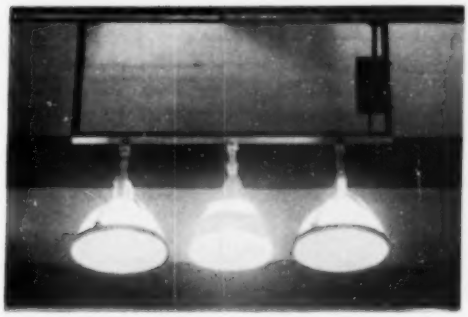

Figure 8. High bay triple unit suspension bracket. Ballast is mounted on the bracket.

cury units provides a soft green glow on the ceilings which produces a very pleasing effect. The lighting level, at floor level, in this area is in the order of 55 footcandles maintained. With the rows of lights being controlled separately, there is sufficient flexibility of illumination, designed roughly at 20-40-60 footcandles, to suit the work tasks, or occasion, as the case may be.

Elimination of Cavern Effect

Throughout the auxiliary bay and boiler house areas it is highly desirable to design for a minimum of glare in the operator's eyes looking from one elevation to a higher elevation. In the boiler house, with the varying elevations and irregularities, this could be accomplished best by the use of prismatic glass luminaires of 200-watt capacity (Fig. 9a). These are located to provide minimum illumination of 25 footcandles throughout the area. This lamp size appeared suitable below the grating floors to insure against annoying upward glare through the gratings. In a few locations in the boiler house where ceiling heights are in the order of 25 feet or more, the high bay unit, employing 300-watt to 1000-watt lamps, has been provided, serviced from lowering type hangers, but in practically every case, care has been exercised to provide illumination on all parts of ceilings as well as on floors and equipment. For the auxiliary bay areas, fluorescent industrial type units have been used with slots provided in the units to illuminate the ceilings which accomplishes the solution to the basic problem of eliminating the "cavern" effect in these areas (Fig. 10). The elimination of "cavern" effect is felt to be a forward move in that it tends to reduce any tendency toward claustrophobia and makes for cleanliness and general cheerfulness about the power plant. Also, work on cable racks overhead is greatly facilitated by use of the upward light component for ceiling illumination (Fig. 9b). It is interesting to note that slotting of the fixtures results in marked decrease in operating temperature of the fluorescent tubes, reductions up to 18° being recorded by the manufacturer on test.

Outlying Buildings

The same considerations were given to the design of the lighting in outlying buildings as they were in the main station building. The functions of the areas were analyzed, and the lighting designed for the function. The same general types of luminaires were also used and, in order to eliminate repetition of discussion, the design in the various buildings will be briefed.

(a) *Yard Service Building.* — This building comprises yard equipment and locomotive repair shop, Yard Master's office, general purpose assembly room and locker and shower rooms. The repair shop lighting design utilizes 1:1 lumen ratio combination incandescent-mercury for general lighting, providing 50 footcandles from high bay units. Continuous row fluorescent lighting is used over the work benches for the localized illumination. The remainder of the building is lighted with opal glass

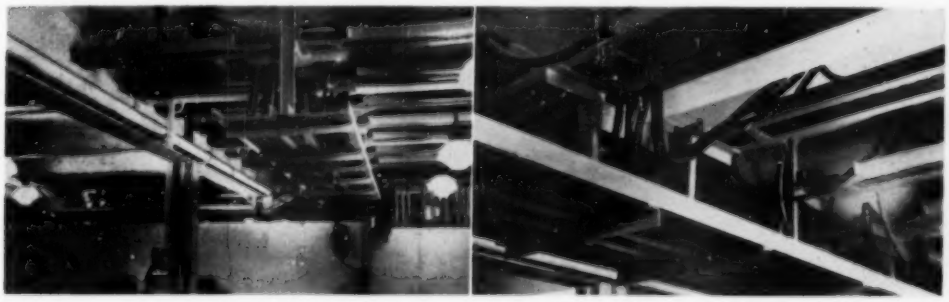

Figure 9. (A—Left, B—Right). Prismatic glass enclosed 200-watt units provide even intensity over ceiling areas, piping, cable racks, etc. to eliminate "cavern effect." Note the ease with which cables can be traced and identified throughout their runs.

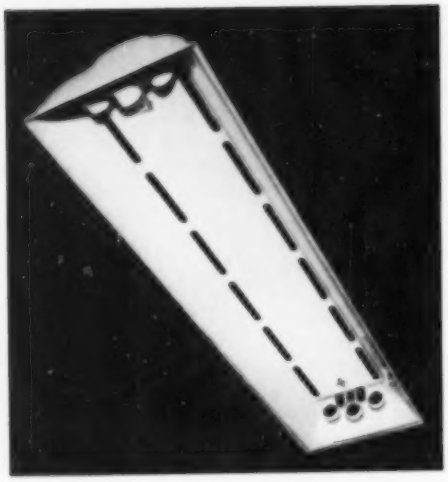

Figure 10. Fluorescent industrial unit with apertures provided for utilization of upward light component to eliminate "cavern effect."

enclosed fluorescent luminaires (Fig. 10). The maintained intensity on the work benches will be between 100 and 125 ft-c; that in the Yard Master's office 50 footcandles; in the locker and toilet rooms 20 footcandles, and 35 in the assembly room, so controlled that, if desired, half the facilities in this room can be energized for flexibility.

(b) *Thaw Shed.* — This building is composed of four cubicles 270 feet long, each accommodating five cars of coal, where hot water is used to thaw the cars of frozen coal. Ordinarily, there is no visual task in the building; however, floodlights have been installed at each end of the cubicles for those occasions when they must be entered.

(c) *Car Dumper House.* — The car dumper unloads the coal by turning the car completely upside down, emptying the coal into hoppers from where it feeds into the conveyors underground. The controls are at ground level, the mechanism and all of the handling equipment are in a subterranean structure extending to a depth of 65 feet. The majority of the luminaires are dust tight prismatic glass enclosing units maintaining an intensity of 25 footcandles.

(d) *Coal Crusher House.* — The coal crusher house problem is similar to the boiler house with its various elevations and irregularities of equipment outlines. Prismatic glass enclosing units are used to maintain an intensity of 25 footcandles.

(e) *Conveyor System.* — There are 9,700 feet of conveyors now built which are capable of handling 450 tons of coal per hour. The initial installation of four boilers requires 80 tons of coal per hour and the additional boilers for the plant extension now under construction will require 60 additional tons per hour. The ultimate installation of six turbo-generator units will require a total of 300 tons of coal per hour. It is important that this "life line" be kept in operation. Although the lighting is not designed for close inspection, the 15 footcandles obtained is intended to be sufficient for oiling and observation. A sufficient number of heavy duty convenience outlets are installed so that portable lights can be used for those infrequent occasions when close visual work is necessary. Porcelain enamel dust tight luminaires are used in the enclosed sections and symmetric street lighting luminaires in the open sections.

(f) *Transfer Stations.* — The transfer stations change the flow of the coal from one conveyor to another and house the necessary control equipment for this function. Prismatic glass enclosing units are used in these locations maintaining 25 footcandles.

(g) *Screen House.* — The screen house, located at the river bank, screens the intake water of debris. The debris is constantly being removed to allow a free flow of water. Combination incandescent-mercury illumination using prismatic glass reflectors is supplied in the high bay areas providing 25 ft-c. Here again metal backing is omitted from the mercury units to light ceiling areas. Vapolets are used below ground level to supply a sufficient intensity for oiling and safety.

(h) *Water Treatment Building.* — Over the treatment tank area incandescent lamps in prismatic glass reflectors are used supplying 15 to 20 footcandles. In the pump area fluorescent luminaires are used with 25 footcandles maintained. The water test laboratory is also located in this building where 75 footcandles of fluorescent lighting is supplied from industrial type reflectors.

(i) *Office and Service Building.* — The office and service building is a general purpose building housing the Superintendent's office, general offices, the mechanical and electrical repair shops, locker rooms, laboratory, large assembly room, kitchen and storerooms. In the offices, laboratory and kitchen, ceiling mounted opal glass enclosed fluorescent luminaires are used supplying 50 to 75 footcandles of general illumination (Fig. 11). This same general type luminaire provides 35 footcandles in the large assembly room and 20 ft-c in the locker and toilet rooms. Glass bottom troffers are installed in the reception lobby where 60 ft-c is maintained. In the shops and storerooms industrial type fluorescent luminaires are used. An intensity

Figure 11. Fluorescent opal glass enclosed luminaire for plant offices.

of 50 to 60 ft-c is maintained in the shops, and 20 ft-c in the open storage areas of the storerooms with a slightly higher intensity in the aisles of the bin storage areas.

Outdoor Lighting

The outdoor lighting falls into three classifications: (a) Substation lighting, (b) Floodlighting, and (c) Roadway lighting.

(a) *Substation Lighting.* — The substations are lighted with refractor type substation units and have been installed in accordance with the manufacturer's specifications. It can be readily observed whether or not the switches are open or closed and the ground illumination is excellent (Fig. 12). It is possible, however, that some additional supplementary lighting may be necessary. Several experiments have been made with the PAR type reflector lamps with good results, and if operating experience later indicates supplementary lighting necessary in these substations, some of these PAR units will be added.

(b) *Floodlighting.* — Floodlighting is confined almost entirely to the north end of the railroad yard and to the coal storage area where 1000- and 1500-watt narrow and wide beam weather tight floodlights are used so that coal can be kept moving regardless of day or night. The floodlights are mounted in groups of three on poles spaced on approximately 200-ft centers, mounted at approximately 35 feet.

(c) *Roadway Lighting.* — Almost four miles of roadway are necessary on this project to connect the various areas and buildings. These roads are lighted in accordance with the "American Standard Practice of Street and Highway Lighting." The road from the main gate house leads past the future 220-kv substation, the two 66-kv substations, and the boiler house, to the office building. In this area where there are high voltage lines, steel pole underground supply is used. The 4000-lumen lamps are spaced on 120-ft centers and mounted at 27 ft 6 inches. Past this section, towards the coal storage area, where the traffic has thinned out and where there are no high voltage lines, wood pole, overhead supply is used. The lights are mounted at 25 feet on approximately 150-foot centers. These lights are all supplied from 6.6 amp series circuits. The system is operated from photoelectric control.

Emergency Lighting

Emergency lighting is from 125-volt storage batteries and contemplates providing sufficient illumination in operating rooms to perform emergency operating procedures. In other areas only sufficient light is provided to permit passage between operating areas. "Exit" lights are provided at all stairway entrances. The emergency light in the control rooms is from reflector type floodlights located above the louverall ceiling, spaced about

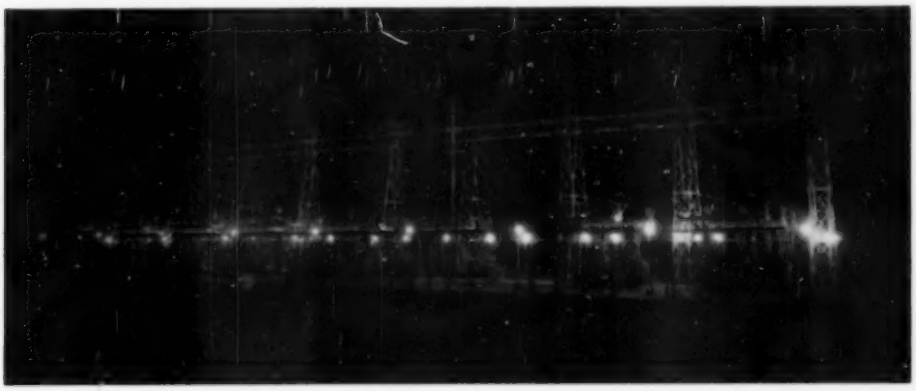

Figure 12. Night view of one of the substations. While illumination in general appears adequate, some supplementary lighting may be indicated after station has operated for some time, which will probably be obtained from PAR type floodlights.

two feet in front of switchboards on 4-ft centers. The receptacles for these lamps are mounted on short "skip" sections between the fluorescent reflectors. PAR floodlights are also provided for turbine room emergency illumination. Two of these are located at each end of the turbine room at the crane rail to flood the turbine room floor.

Conclusions

Great strides are being made in the lighting of generating station properties, but the problems are so complex that much still remains to be done. For the lighting of general areas, it is highly desirable that the brightness contrast between luminaire and the background be kept to a minimum. This has been accomplished by using industrial fluorescent reflectors with apertures, and also with prismatic reflector refractor units to eliminate what we have termed "cavern effect," and by using properly selected paint and careful selection of fixtures.

For control rooms and for high intensity control board lighting with a minimum of annoyance from specular reflection in the instrument scales in control rooms with switchboards located at right angles to each other, the best results will be obtained from the use of a solid ceiling lighting source. This source, depending on room proportions, can be totally indirect illumination from lighting units located behind switchboards, from some form of artificial skylights such as solid glass or plastic ceiling, or from a suspended ceiling of egg-crate louver of metal or plastic with high intensity light sources above the false ceiling. For high intensities the plastic egg-crate ceiling has distinct advantages. The egg-crate ceiling also has the advantage of facilitating good air distribution for the air conditioning system.

The visibility of switchboards in general is much improved with use of flush type devices and the lighting problem would be materially lessened if switchboard instruments were completely designed to be furnished with all-glass covers. Internal lighting of instruments is contrary to the fundamental principle of good lighting, that of maintaining even brightness on the panel fronts to improve visibility and reduce eyestrain, and therefore, should not be used. Instrument scales and switchboard name-plates should be white with black letters to provide greatest visibility.

For turbine rooms and other high bay areas, the 1:1 lumen ratio combination mercury-incandescent high bay prismatic glass units provide excellent quality of illumination with negligible stroboscopic effect.

Interspersing of supply circuits through the plant provides insurance against complete loss of illumination in any one area.

Roadway lighting, often neglected in generating plant lighting design, is highly important for safety and for protection of property.

The lighting of offices and workshops in the power plant is deserving of the same good engineering attention that we give to our customers' offices and shops.

Lighting of a generating station is a major engineering undertaking and affords the utility an excellent opportunity to demonstrate to employees and customers, the benefits and advantages of well-engineered lighting.

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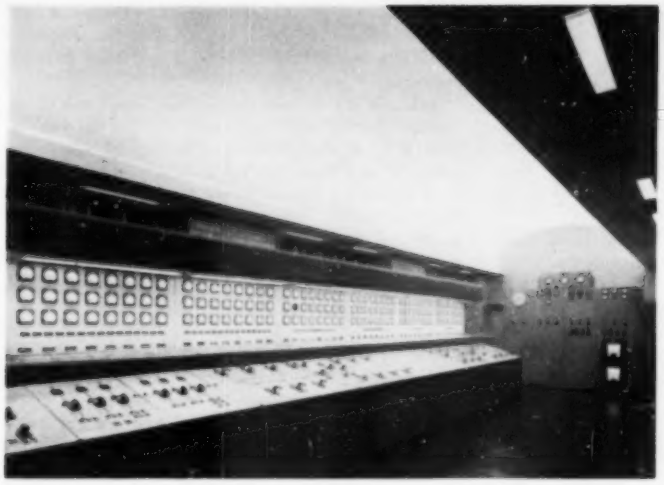
DISCUSSION

PAUL E. KING*: The authors are to be commended for an excellent paper on modern generating station lighting. Few people realize, until they visit one of these modern plants, the various lighting problems that are involved.

I am in complete agreement with most of the lighting methods used in this installation; and I should particularly like to commend the authors for the use of lighting equipment utilizing an upward component. Visual inspection of overhead piping, conduit, cable racks, etc. is very important in a plant such as this. Operators and maintenance personnel have given hearty approval wherever this type of lighting has been used.

I cannot entirely agree, however, with the solution offered for Control Room lighting. It is true that a system of louverall or plastic ceiling lighting is perhaps the optimum for good general lighting. Brightness contrast is reduced to a minimum, and the room in general should be very comfortable. However, a Control Room in a modern generating station, being the nerve center of the entire plant, is a room of action. At times when trouble occurs, complicated switching must be done; and the Control Room operator must be constantly alert to danger signals on his instruments. Therefore, it seems to me that the center of the attraction in the room should be the instruments themselves and not the other parts of the room. Since brightness contrast is one of the important factors in our ability to see, I firmly believe that the instrument area should be the brightest part of the room. Our eyes quite naturally are attracted to the brightest area in any room.

*Engineering Department, Gilbert Associates, Inc.



Electrical Transmission Control Room, Russell Station, designed for Rochester Gas and Electric Corp.

A case in point is the Control Room lighting at the new Russell Station of the Rochester Gas and Electric Corporation at Rochester, New York. In this installation, the duplex board and bench board have been combined into a single unit. Instrument lighting was planned as a part of the board; and a continuous row of incandescent lens units directs the light at the instruments from both top and bottom, effectively eliminating directional shadows, and the viewing angle is such that no specular reflection results. Approximately 60 footcandles of vertical illumination is provided on the instrument faces. A slimline fluorescent cove, contributing 32 footcandles, completes the lighting scheme.

A rather interesting innovation, that of dimmer control for all of the lighting, is installed in the room. Two dimmers are used, one for the instrument board and one for the overhead general lighting. Thus it is possible for each individual operator to select the intensity that he finds most comfortable. This tends to eliminate the age old expression of "there is too much light, or there is not enough light." Interestingly enough, most of the operators seem to prefer the highest intensity, but some of the night operators prefer a much lower intensity.

To my mind, the lighting fulfills the purpose for which it was designed, that of focusing the attention of the operators on the instruments.

Credit for this installation is due Mr. L. R. Scott, Electrical Engineer for the Rochester Gas and Electric Corporation.

C. E. Egeler*: The paper reflects the authors' comprehensive understanding of the variety of lighting problems of a modern generating station, which involved complete familiarity with the operating aspects involved. The standards of illumination, and the full appreciation of the importance of brightness control, represent the best thinking of today, and incorporate an understanding of a need for taking care of the worker's comfort, to which good lighting, as well as provision for the physical aspects of the working environment, can contribute so much.

The extensive discussion of the lighting of the control rooms is indicative of the relative importance given to this lighting problem by plant managements. The solution embraces one of three approaches which have been used, namely:

1. Controlled lighting from sources located particularly with reference to avoiding reflections by meter covers.
2. The use of low brightness sources in direct and indirect.
3. Large area (ceiling sized) sources presenting uniform brightness areas toward the meter faces, and of minimum brightness values in these directions.

The treatment discussed in this paper is an example of the third approach. For the higher board face levels of illumination specified, it will be interesting to learn whether a consciousness of the large area of brightness, is disturbing to the control room operators, after they have worked under the lighting for an appreciable period. A lack of sharp contrasts in the brightness patterns in the normal line of vision is undoubtedly very helpful in this connection.

At different times, rather unusual and special lighting designs have been used to solve the control room lighting problem. One such is the use of ceilings, specially contoured, to provide indirect lighting of uniform brightness. Slide 1. This chart shows the arrangement used at a TVA plant in Tennessee. Good visual comfort is reported from this arrangement using 48 200-watt filament lamps special projector units with reasonably good lighting levels on both the meter board faces and at the desk area. (Photos—Slides 2 and 3.)

Another arrangement of recent design is that at a new central station in western Pennsylvania. Here, the effort was particularly to obtain control of the light by special location of fluorescent units employing

*General Electric Co., Nela Park, Cleveland, Ohio.

ribbed prismatic glass covers. The arrangement is shown in the photograph (Slide 4) and the footcandle levels of 30 at the top of the board give brightness ranging from approximately 12 footlamberts at the top with 5 at the bottom, resulting from board for reflection factors of 35-40 per cent. The brightness ratios front lighting unit to top of board are low — within 2 to 1. With allowance for depreciation, provision for higher footcandle levels is indicated as an approach to more ideal seeing conditions.

Just what brightness ratios within the usual lines of vision are permissible, is a subject for further analysis and discussion. It may be that about 3 to 1 is as far as one can go, and it is reported that the control room at Sunbury reaches this figure. (Insert A.)

Another approach to the use of controlled light for the control boards is the use of small diameter fluorescent sources located in polished parabolic metal troughs, as shown in sketch Slide 6. This arrangement gives a range of 28 footcandles at the top of a 7-ft. board to 18 footcandles 2 feet from the floor from slimline lamps operating at 300 milliamperes. For a light floor the bottom figure is increased about 50 per cent giving excellent uniformity top to bottom. To obtain good overall brightness balances, indirect lighting of the ceiling over the board from similar units and the installation of down lights over the desks would provide a combination warranting further consideration.

There would seem to be a considerable range of costs for the different systems, and no doubt this factor will be given primary attention in many cases, possibly more than would be warranted in relation to the importance of the lighting.

The author's use of fluorescent lamp units giving upward light to avoid the so-called cavern effect of boiler spaces, is to be particularly commended. Too often the lighting involves bad direct glare from the lamps, as well as less light on the walls and overhead surfaces.

Maintenance of the lighting equipment should receive much greater attention than is the usual practice in generating plants. With management's willingness to go to added expense to provide lighting equipment which will meet the special seeing tasks, too often the initial result is achieved by only one-half as the result of no provision for periodic maintenance. Also, in the selection of lighting equipment, only designs should be selected which can be easily maintained since this involves direct labor costs which are budget items and which the power companies watch as do their industrial customers.

DAVIS H. TUCK*: Sunbury is without question the best lighted generating station in the country, the primary reason for this being that the owners, Pennsylvania Power and Light Co., and the Consulting Engineers, Ebasco Services, completely recognize the many benefits, at comparatively low cost, resulting from good lighting and have the courage of their convictions.

The attention given to environment by the use of light colored surfaces is another indication of the acceptance of modern conceptions of lighting and their practical application.

Although the authors implied the importance of reliability and low maintenance cost, they did not make an issue of it. In my opinion the reliability or trouble-free operation of lighting equipment is of prime importance in a generating station where twenty-four-hour uninterrupted service year after year is required. Maintenance and lamp replacements should be simple and require minimum upset of routine operations. "Stunt" lighting systems, which might be in order for a specialty shop or night club should be discouraged in a generating station.

The utilities are the logical exponents of good lighting. They properly and aggressively advise their customers to bring their lighting up to modern standards and justify their recommendations by the benefits that will accrue to the customer due to adequate illumination. The utilities, therefore, cannot afford to employ lighting methods or equipment that is not at least as good as they recommend to their customers. Every utility structure should serve as an example of the best lighting practice lest their customers say "Doctor, cure thyself!"

H. F. CARROLL AND W. B. MORTON*: Mr. King has offered an effective means of solving the problem of providing illuminations on the instruments and avoiding both shadows under devices and specular reflection in the glass, based on his contention that the switchboard should be the brightest illuminated surface in the room. If the lighting engineer starts out with this as a premise, then Mr. King's solution appears to offer a very satisfactory answer; however, the authors of the paper feel that the infrequent occasions that trouble is encountered in the station, compared with the many hours that an operator must live in the control room seem to indicate that the lighting should be based on visual comfort and everyday requirements of the operator provided that in times of emergency, there still is adequate illumination to perform the emergency operations successfully.

The suggested arrangements and types of lights for switchboard illumination suggested by Mr. Egeler will provide for solution to some of the problems pointed out in the paper, such as adequate intensity on the instruments and elimination of specular reflection in the instruments from the lights immediately over the panel at which the operator might be taking readings; however, any form of direct lighting over the switchboards in a room such as described in the paper, where the switchboards wall-in the operator on all four sides of the room, tests indicate that specular reflection will be noted in the instruments from any type of direct illumination at right angles to the board at which the operator is looking.

We recognize some facts and fallacies in the lighting of control rooms. Room location, room proportion, construction, control board design and placement and operation all enter into the problem. From studies that

*Electrical Engineer, Redding Ridge, Conn.

*Authors

have thus far been made and data compiled, there is every indication that one recommendation cannot be set up and ear-marked "this is it."

Mr. Egeler emphasizes a point that should be continually emphasized and that is the matter of maintenance of the electrical equipment. Too often good lighting is nullified by lack of maintenance that could very well keep the lighting in a continual stage of its maximum efficiency. His point that lighting designs should consider the continuing maintenance costs is also a good one as the cost of maintenance can well sky-rocket if this point is not kept in mind by the lighting designer. An example of this would be high bay units in a boiler area with no access to the units for maintenance or relamping, requiring long extension ladders, whereas the design can readily provide lowering type hangers and make the maintenance procedure very simple. The cost of the lowering hangers represents a fraction of the cost of maintaining equipment under these conditions where no hangers or other provisions are made in the design for adequate maintenance.

Laundry Lighting Requirements*

by A. W. Kakilty

Rebuttal to discussion by Arthur A. Eastman**

A. W. KAKILTY: Mr. Eastman very kindly remarks in his discussion that the work done with the Visibility Meter to "evaluate lighting — in the laundry leaves much to be desired." That is a masterpiece of understatement. But the same statement can be applied to getting the correct lighting accepted in residences in general or in even agreeing among ourselves just what is "correct lighting" and in "selling" that correct lighting — if we knew what it was — to the housewife. Likewise it can be applied, doubled and redoubled, to the color situation in fluorescent lamps.

But to return to the question of color preference which seems to trouble Mr. Eastman I must confess that I was a little surprised myself and was all prepared to discard the entire Table I. I knew that it would provoke unnecessary controversy. I say "unnecessary" because I distinctly stated in the paper that in this investigation we did not possess the facilities to go deeply into the color situation. Furthermore mine was a field job, not a laboratory job; tests being conducted in a real existing residential laundry and not in a laboratory. But the table was left in with "malice aforethought" for these reasons:

1. I am interested in getting some sort of agreement on colors in fluorescent lamps.
2. I am more interested in getting some sort of a prescription for Mrs. Jones' ironer. So we can say, "What you need is a certain wattage lamp of ——— color for best ironing results."
3. Since I always "thought" that I could personally see better with the Daylight Incandescent (but never could prove it), the table interested me. (I made none of the readings myself, but all readings by all observers followed the same pattern.)
4. Without exception, in practical (not laboratory) trials in which "daylight" fluorescent lamps were tried on close tasks the reports came back to me that observers "couldn't see" as well as might be expected from Mr. Eastman's remarks (and which I ordinarily would have expected myself).
5. About the time Mr. Eastman was deciding that you could see a little better with more "blueness" in the lamp another equally reputable laboratory issued (May 1949) a well authenticated article extolling the value of the "warm" white color for better seeing. It advises that this particular "warm" (I am using no trade designations) color "contribute to better seeing"; "see better under this than under other color temperatures."
6. Having been one of the original developers of "combination lighting" in which we combined mercury vapor lamps with incandescent lamps to get approximations to "daylight" (before the advent of fluorescent), I am well aware of the difference in types of spectrums between any arc type lamp and any incandescent. Therefore I am fully aware of strange things which can occur in observing any color under any illuminant possessing a band spectrum. This could happen at the ironing table.

So I am not convinced anyway, and neither is the mythical Mrs. Jones who has this ironing problem.

As for some of Mr. Eastman's other objections, the Visibility Meter is listed as a "field instrument (and we paid good money for it, for that purpose). I notice it so listed in the I.E.S. Lighting Fundamentals Course of January 1949. So we do not (in the field) develop any elaborate stands or racks to maintain any rigid set distance. We did, however, measure that distance and attempted to keep it reasonably constant. It occurs to me that we could rigidly attach a small folding rule to the front of the instrument; pull it into place and, behold, our distance is fixed. (There is no charge to the manufacturer for that patentable suggestion.)

As to the "significant" figures in the table! We, too, have studied statistics. If the average of Smith's readings is 10 footcandles (and he should be able to read that close) and Brown reads 15, I would put 12.5 in the table. It's just that simple.

Finally, the I.E.S. Handbook says, "The spectral response characteristics of the human eye vary between individuals, with time, and with the age and state of health of any individual, to the extent that the selection of any individual to act as a standard observer is not scientifically feasible."

So I imagine that after we argue this all out, Mrs. Jones will probably choose the color lamp that matches her dress!

*November, 1949, p. 871.
**January, 1950, p. 27.

Effect of Source Size Upon Approach Light Performance

By G. M. KEVERN

Experience has shown that during low visibility conditions, an appreciable error is introduced if approach lights are considered to be point sources. An investigation was conducted to determine the effect of source size upon the visual range of approach lights, and to determine suitable requirements for inclusion in specifications. A solution to the problem is presented herein, but the solution is admittedly approximate, as additional basic research is required. This paper is presented in the hope that discussion and research will be stimulated.

DURING the development of approach lighting systems, it became apparent that if approach lights were assumed to be point sources, as was done in all previous calculations,[1] an appreciable error might be introduced. Preliminary calculations and tests showed that lamp assemblies having a relatively large source size would not have as great a range during heavy fogs as conventional total candlepower measurements would indicate. An investigation was consequently initiated to determine the most practical solution to the following problems, utilizing presently available information:

1. Determination of the effect of apparent source size upon the visual range of lamp assemblies used as approach and runway lights during low visibility conditions.
2. Determination of suitable source size requirements for inclusion in specifications covering high intensity approach and runway lamp assemblies.

Basic Data

It is a well known fact that source size has a decided effect on the intensity of illumination which the source must deliver at the eye in order to be visible. Scientific literature contains many articles on this subject, one of the most notable being a paper by P. J. Bouma[2] summarizing the work of six other authors. None of these data are, however, sufficiently complete to permit a numerical solution of the problem.

Extensive research of the threshold values for the human eye have been reported in a paper by H. R. Blackwell.[3] The calculations and conclusions contained herein are based entirely upon the basic laboratory data reported in Blackwell's paper. The conclusions are confirmed qualitatively, but not quantitatively, by laboratory and field tests conducted by the Air Materiel Command, and by one manufacturer actively engaged in the development of approach lights.

Source Size Factor

Since engineering calculations pertaining to approach lighting systems are normally based upon a point source, the most logical solution is to determine a means of converting an actual source into an equivalent point source. The term "source size factor" is, therefore, defined and calculated in Appendix A. The analysis necessarily included several arbitrary assumptions, as data definitely correlating laboratory and service conditions are not available.

Source size factors covering all anticipated lamp assemblies have been calculated, and are plotted in Fig. 1. A recommended method of testing is outlined in Appendix B.

Summary

It is evident that when runway and approach lighting systems are being designed, the effect of source size can no longer be ignored. A simple and convenient method of evaluating lamp assemblies with respect to effective source size has been developed and is presented in Appendices A and B, and Fig. 1. This method is admittedly approximate, but more exact methods are not feasible until more information is obtained by basic research on the following points:

1. Background brightnesses during daylight fogs.
2. Correlation of laboratory and practical pilot visual thresholds.
3. Effect of non-circular shapes.
4. Effect of non-uniform brightnesses.
5. Effect of grouping two or more small sources.

It is hoped that publication of this paper will result in (1) recognition by approach and runway

A paper prepared for the June, 1947 meeting of the I.E.S. Committee on Aviation Lighting. Mr. KEVERN is Chief of the Lighting and Accessories Unit, Equipment Laboratory, Engineering Division of the Air Material Command, Wright Field, Dayton, Ohio.

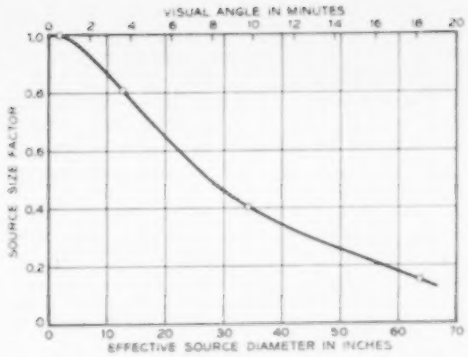


Figure 1. Comparison of point and actual sources.

light manufacturers of the fact that effective source size should be held to a minimum; (2) Stimulation of research upon the above problems. These problems would make excellent subjects for research leading to theses; and (3) Stimulation of discussion, in order that all presently available information may be correlated, and any controversial aspects resolved.

Acknowledgment

The dependence of this practical solution of the source size problem upon the laboratory data contained in Mr. Blackwell's paper is emphasized, and his assistance is gratefully acknowledged.

References

1. Kevern, G. M.: "Approach and Runway Lighting for Adverse Weather Conditions," ILLUMINATING ENGINEERING, Vol. XLI (June, 1946).
2. Bouma, J. P.: "Illuminating and Blackouts," *Philips Technical Review*, January, 1939.
3. Blackwell, H. Richard: "Contrast Thresholds of the Human Eye," *Journal of the Optical Society of America*, November, 1946.

APPENDIX A

COMPARISON OF ACTUAL AND POINT SOURCES

1. In order to compare sources having an appreciable size with point sources, the term "source size factor" is defined and calculated herein. Although sometimes called "efficiency," it will be apparent that the factor is not an efficiency in the true sense of the word. It is recognized that, due to the many variables involved, and the lack of certain basic data, only approximate comparisons can be made at the present time.

2. The necessary assumptions are listed and explained as follows:

a. All sources are assumed to be circular in shape and of uniform brightness, as laboratory data on other shapes and non-uniform brightnesses are not available. This assumption necessitates an arbitrary test procedure, as outlined in Appendix B.

b. For purposes of comparison, a point source is assumed to be a circular source of uniform brightness which subtends a visual angle of 0.595 minutes. This source is a point source at all adaptation brightnesses, and is the smallest source for which laboratory data are available.

c. Visibility distance is assumed to be 1,000 feet, as an approach light, to be useful, must be visible at least 1,000 feet. Greater distances result in a smaller visual angle, and lesser distances need not be considered as the candlepower should be well above the threshold value. It is not feasible to design approach lighting systems for atmospheric conditions in which the lights will be visible for distances appreciably less than 1,000 feet.

d. Background brightness is a widely varying factor which has considerable effect upon the source size ratio. The limiting condition of heavy daylight fog is therefore selected, and a background brightness of 10 footlamberts is estimated.

e. It is obvious that laboratory threshold values must be multiplied by a "safety factor" to obtain practical threshold values for the pilot of a fast moving airplane. In the absence of reliable test data, a safety factor of 400 is assumed. (A larger safety factor must be used with the laboratory threshold values contained in Blackwell's paper, than with values previously used.)

3. The necessary symbols are listed below. The subscript p is used to denote a point source, and the subscript L is used to denote the actual source under consideration.

- S = Source size factor.
- B_a = Background brightness in footlamberts.
- b = Threshold brightness increment, in footlamberts. (laboratory).
- A = Area of source, in square feet.
- V = Visual angle, in minutes.
- I = Threshold candlepower (practical).
- C = Contrast $\dfrac{b}{B_a}$.
- D = Observation distance, in feet.
- d = Diameter of source, in feet.
- F = Safety factor.

4. The source size factor is defined as follows, remembering that practical values of threshold candlepower must be used.

$$S = \frac{I_p}{I_L}.$$

5. The practical threshold candlepower may be expressed as

$$I = FbA + B_aA$$

(The term B_aA has normally been neglected in previous engineering calculations, but a few sample calculations will show that its omission, although permissible under nighttime conditions, will result in appreciable error during daylight conditions.)

6. The visual angle is determined as follows:

$$\tan \frac{V}{2} = \frac{\frac{1}{2}d}{D}$$

$$V \text{ (in minutes)} = \frac{d}{.000291D}$$

(An approximation sufficiently accurate for the small angles under consideration.)

7. $$A = \frac{3.14\,d^2}{4} = \frac{3.14}{4}\,(.000291\,DV)^2.$$

8. By substitution and cancellation

$$S = \frac{(Fb_p + B_o)\ A_p}{(Fb_L + B_o)\ A_L}$$

$$= \frac{(Fb_p + B_o)\ V_p^2}{(Fb_L + B_o)\ V_L^2}$$

$$= \frac{(FC_p + 1)\ V_p^2}{(FC_L + 1)\ V_L^2}.$$

9. The source size factors tabulated below and plotted in Fig. 1 were calculated using contrast values obtained from Table VIII of Blackwell's paper, and the following assumptions:

$F = 400$ $\quad$ $D = 1{,}000$ feet

$V_p = 0.595$ minutes $\quad$ $B_o = 10$ footlamberts

d	V_L	C_L	S
2.08 inches	0.595 minutes	0.871	1.00
12.6	3.60	0.027	0.81
33.8	9.68	0.00574	0.40
63.5	18.2	0.00373	0.15

Appendix B
Test Methods

1. The most widely used existing method of specifying and testing the light distribution of approach and runway lights is outlined as follows:

a. Provide specification curves showing minimum candlepowers, at all angles, which must be equalled or exceeded.

b. Perform a conventional photometric test, obtaining total candlepower values.

c. Plot both specification and test candlepower distribution curves on the same sheet of paper.

2. The simplest and most convenient means of modifying the above method to include source size evaluation is as follows:

a. Provide specification curves showing minimum candlepower values for point sources.

b. Include in the specification a curve of source size factors plotted against effective source diameters. (This curve would be a duplicate of Fig. 1, and is determined using the methods and assumptions described in Appendix "A.")

c. Specify that, for any given lamp assembly, the total candlepower (measured by conventional photometric methods) in any direction will equal or exceed the specified minimum value divided by the source size factor.

d. Determine the source size factor for the lamp assembly being tested as follows:

(1) Plot a curve of total candlepower, against aperture diameter, with data obtained by placing circular apertures of several different diameters six feet in front of the center of the lamp assembly, centered upon the photometric axis. (The six foot distance was determined primarily by the physical construction of the Air Materiel Command's photometric laboratory.) All candlepower readings should be taken at the same angular setting, preferably along the axis of the light beam.

(2) Consider the effective source diameter to be equal to the diameter of the aperture which passes 90 per cent of the total candlepower of the lamp assembly.

(3) Using the above diameter, obtain the source size factor from the specification curve.

e. Plot candlepower distribution curves, showing both total candlepower test values, and the specified minimum values divided by the source size factor, on the same sheet of paper.

3. Explanatory notes:

a. In all of the above tests, the photometric distance (distance between cell and center of light source) should be great enough to insure that an accurate measurement of total candlepower is obtained. The photometric distance will then have no effect upon test results, since all visual angles are based upon the assumed 1,000-foot visibility distances.

b. In brief, the above procedure results in replacing the actual source, for purposes of calculation, with a circular source of uniform brightness, whose diameter is determined in accordance with Paragraph 2d(2) above.

c. The above method may be applied to a lamp assembly consisting of a group of small sources as follows:

(1) Each small source should be considered individually, taking into consideration the angles which the source is intended to cover.

(2) Candlepowers of adjacent sources should not be added.

Spacious bedroom closet converted into a man's complete dressing unit is lighted by 5 concealed fluorescent lamps. Closet ceiling fixture provides general illumination; 4 other fluorescent installations highlight mirror area, clothes, tie and shoe racks. Photo courtesy of Sylvania Electric Products, Inc.

Lighting A Classroom

LIGHTING OBJECTIVE: To illuminate a high school classroom in a functional manner utilizing space between beams.

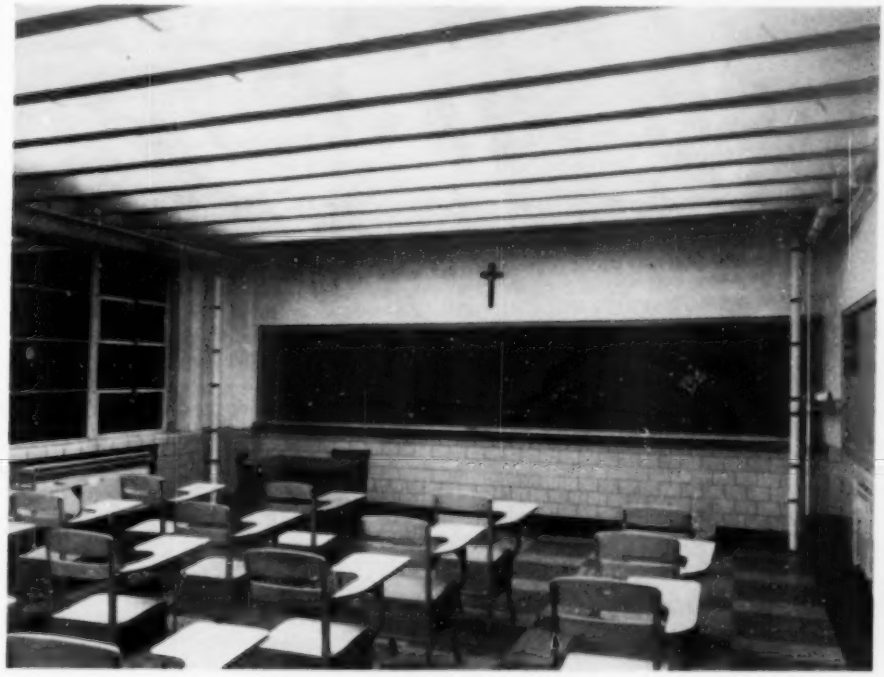


Figure 1.

Installation at Canisius High School, Buffalo, New York.

Architect: Albert A. Rumschik **Electrical Engineer: Howard M. Sharp**

General Information: The reinforced concrete structure of the building produced ceilings studded with concrete beams 6 inches wide. Height from floor to bottom of beams is 9 feet 8 inches; each recess between beams is 20 inches wide and 12 inches deep. The room shown above is approximately 23 feet by 30 feet. Colors and reflectances are indicated below:

Ceiling	— flat white	— 85%
Walls	— buff	— 60%
Wainscoting	— buff tile	— 50%
Floor	— asphalt tile, alternate blocks:	
	grey	— 24%
	coral	— 16%
Woodwork	— medium light oak	— 26%
Furniture	— natural birch	— 60%
Chalkboard	— green	— 14%
Tackboard	— tan cork	— 26%

(over)

A.I.A. File No. 31/16

Figure 2.

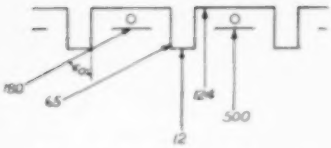


Figure 3. Luminaire Brightnesses. (Footlamberts).

Installation: Beginning at the second recess between beams from the front of the room and continuing in 12 consecutive recesses, a 16-foot luminaire with two 96-inch, 200 ma 3500K slimline lamps was installed. The lamps are shielded sidewise by the beams and from below by Albalite panels 10 inches wide installed directly beneath the lamps. (The five inches of space between the sides of the glass panel and the beams permits circulation of air.) Two-lamp ballasts are mounted in every other 8-foot section; the wiring is such that the lamps on the inner side of the room can be controlled separately.

The glass panels are held in frames hinged along one side. These are easily opened for cleaning and relamping.

After 100 hours of operation the average illumination on chair arms was 56 footcandles; estimated in-service value is 45. This requires 2.5 watts per square foot of floor area.

Room brightnesses are as follows:

Task (65% RF)	— 45 ft-L
Floor	— 12.5 ft-L
Wainscoting	— 18 ft-L
Chalkboard	— 6.6 ft-L
Tackboard	— 10.5 ft-L
Wall above chalkboard	— 24 ft-L

Luminaire brightnesses are indicated in Fig. 3. No portion of the luminaires is visible within an angle of 16° above the horizontal to a student seated at the back wall.

The luminaires were designed by H. M. Sharp, built by the Zane Manufacturing Company of Cambridge, Mass., and installed by the Robertson Construction Company, Buffalo, New York.

Lighting data submitted by Howard M. Sharp, 82 Smallwood Drive, Snyder, New York as an illustration of good lighting practice and to aid in the design of similar installations.

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Series XV 2-50

Permanent Gloss Standards

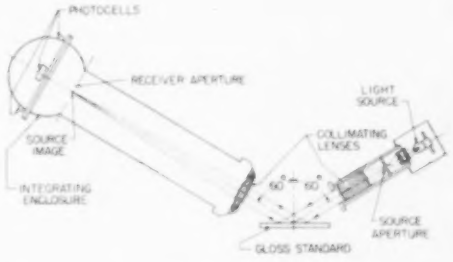
PERMANENT gloss standards, covering the entire gloss range of nonmetallic commercial materials, are now available from the National Bureau of Standards. These standards, which may be used to calibrate any 60° specular glossmeter in the range from matte to high gloss, are made of ceramic materials for permanence, and the surfaces have been specially chosen for similarity to commercial materials whose gloss is important. Sets of the 60° specular gloss standards may be ordered from the National Bureau of Standards, Washington 25, D. C. for $70.00 a set.

Measurement of gloss is becoming increasingly important in many industries. For example, high-gloss paper is required for good reproduction of halftone prints, and low-gloss paper for easy reading of material in type. Building interiors must range from semi-gloss to matte to prevent eyestrain caused by reflected images of the light sources. Gloss of a paint finish should always be adjusted to the use of the finish. Outdoor finishes, such as automotive enamels, have high gloss for permanence, whereas matte finishes are given most war goods for low visibility. Gloss measurements are also important in defining the wear resistance of plastics and ceramics.

The gloss measurement is essentially a simple one. When a specimen is illuminated at some angle from the perpendicular, the proportion of the light reflected at angles near that of mirror reflection is defined as gloss. A critical part of the definition of gloss, however, is the amount that the reflected beam may depart from the strict direction of mirror reflection and still be counted as contributing to gloss. With glossmeters commercially available at the present time, replacement of the lamps, for example, may introduce instrumental error unless readjustment is made. The new gloss standards permit a rapid check of instrument calibration at any time and give a basis for readjustment of the instrument if required.

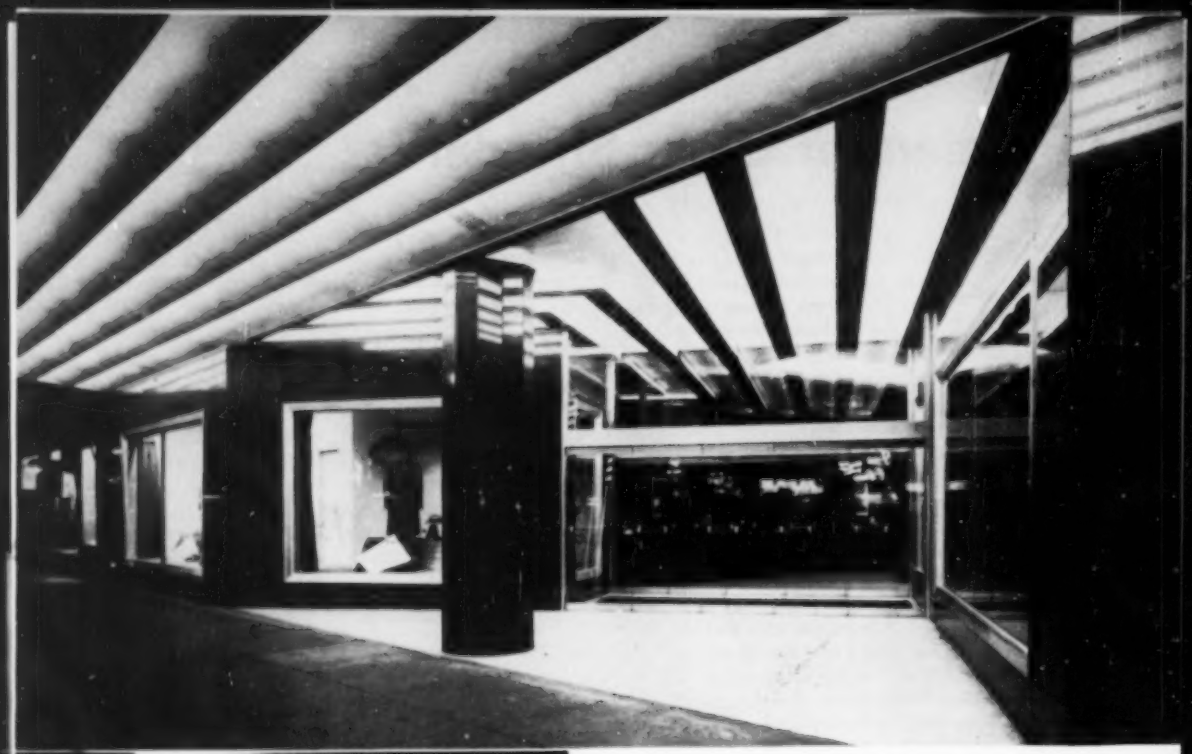
The gloss standards have been prepared according to ASTM Method D523 for the 60° Specular Gloss of Paint Finishes. A set consists of two white Vitrolite plaques having nominal gloss values 1 and 90, and eight glazed ceramic plaques with nominal gloss value 10, 20, 30, 40, 50, 60, 70 and 80. Each plaque, approximately $4\frac{1}{4}$ inches square, is engraved with the nominal gloss value followed by a serial number. The edges and backs of the ceramic plaques are coated with glyptal cement to prevent absorption of water.

The plaques are measured for 60° specular gloss according to the ASTM method, using a glossmeter calibrated with the gloss reference standards of the National Bureau of Standards. These measurements include both the true gloss and a diffuse reflectance component. Corrected gloss values are obtained by subtracting the 0-60° luminous directional reflectance measured with an ASTM receiver aperture. The corrections for each standard are included in the certificate accompanying each set. The gloss values for standards above 15 are given to the nearest gloss unit; below 15 to the nearest tenth of a unit. .... Even with the aid of standards it is not possible to do precise gloss measurement in the medium to high gloss range unless the glossmeter used meets very closely the aperture requirements of ASTM Method D523, or unless the reflected light flux distribution of the specimen and standard are nearly identical. Since it is not practical to meet the latter requirements, it is desirable to make a test for the former. This may be accomplished by adjusting the instrument to read correctly the gloss of a highly polished surface, such as the "90" standard, and then reading the gloss of a high-gloss surface having poorer image-forming characteristics, such as the "80" or "70" standard. If under these conditions the instrument reading for the second standard does not agree closely with the reported value, the instrument should not be used for high-gloss measurement without readjustment, preferably by the manufacturer.



The schematic diagram of the NBS glossmeter illustrates the procedure for calibrating the gloss standards issued by the Bureau. In this instrument, the geometric variables are controlled to the desired accuracy.

Reprinted in part from the *National Bureau of Standards Technical News Bulletin*, Volume 33, No. 10, October 1949, with the permission of the U. S. Department of Commerce, Technical Reports Section. The entire article with additional illustrations may be found on page 121 of that publication.



The Modernization of a Department Store

IN the refurbishing of an old building to accommodate a new department store in Cleveland, the architects and lighting consultants were confronted with the usual problem of creating an attractive modern atmosphere for the effective display and sales of a wide variety of merchandise. Except for the stipulations that air-conditioning ducts had to be accommodated, the original sprinkler-head pipes and locations left essentially unchanged, corporate opinions and policies abided by, the load limits of electric circuits not exceeded, and a predetermined budget limit rigorously adhered to, the professional specialists responsible for doing an effective face-lifting job were left with a reasonably free hand. The very creditable results are typified in the four accompanying illustrations. Ward and Conrad were the architects; John Paul Jones, Crary & Miller the electrical engineers. The store is Lindner-Davis, a new unit in the Allied chain.

TRAFFIC is guided by lighting, as illustrated in this aisleway leading to elevators. **Note the fluorescent-cove-lighted ceiling and the accent cove lighting above the elevator doors. Show-case counters are brightly lighted within, and from overhead high-hat units.**

ENTRANCE lighting features an unusual marquee and a pattern of overhead lighting intended to guide the inquiring gaze of the observer (and thereby also to lead his feet) to the main entrance and through the all-glass doors into the interior. To provide the desired high level of illumination and reduce the maintenance problem to a minimum, double rows of cold cathode fluorescent lamps were spaced approximately 30 inches on centers; to reduce the drop of intensity during cold weather, these tubes were totally enclosed in metal reflectors with plastic diffusing covers.

UPPER FLOORS presented the additional requirements of complete flexibility of display arrangement and the avoidance of any particular traffic pattern. To provide about 35-40 footcandles of general illumination and to avoid the monotony of small fixtures, 4 x 4 ft fixtures were recessed into the ceiling. Each unit contains six 40-watt fluorescent lamps, and sockets for four incandescent lamps to provide for desired color-mixture. Each incandescent lamp is fitted with a metal reflector which extends downward into one of the 4 x 4 x 4-inch egg-crate louver cells. The basic use of fluorescent lamps was considered "doubly important to reduce the air-conditioning load."

MAIN FLOOR consists chiefly of counters and backcases arranged in islands. To give about 35-40 footcandles on the counter-tops, recessed high-hat units with diffusing lenses are aligned in the ceiling along, and about two feet in front of, the aisle-edges of the counters. To accomodate the use of the high-hat units and still avoid the monotony of too great an expanse of circular rings in the ceiling, general lighting is provided by island coves equipped with single strips of fluorescent units. The resulting overall lighting pattern is pleasing to the eye and also is effective as a traffic guide.

A.I.A. File No. 31/14

Changing Office Lighting for Comfort

LIGHTING OBJECTIVE: To provide approximately 50 footcandles general illumination for continuous reading and checking of figures where glare from conventional glass-covered fluorescent luminaires had caused eye fatigue and discomfort.

Installation at Pacific Gas and Electric Company, 445 Sutter Street San Francisco, California

General Information: The visual task of reading small figures, pencilled notes, and carbon copies on variously colored office forms required the reduction of both direct and indirect glare. The ceiling and upper walls of the 12 ft x 18 ft x 10 ft area are painted a flat white with a reflection factor in excess of 75 per cent. The flat buff walls have a reflectance greater than 50 per cent, the beige rug — 25 per cent, and the light linoleum working surfaces — 25-30 per cent.

Installation: The original installation of conventional fluorescent URC type luminaires producing approximately 60 footcandles of illumination caused numerous complaints of constant eye fatigue and discomfort. The small office shown above, typical of the twelve floors of office space (55,000 square feet with 900 lighting units), was relighted as a test. The four URC luminaires which are mounted two feet below the ceiling and eight feet apart, were each relamped with four 40-watt 3000K fluorescent lamps (3500K were used formerly) and the Alba-Lite cover glass was replaced by Corning No. 66 Mona-Lite diffusing glass. Immediately after these changes all complaints ceased. An average illumination of 53 footcandles is provided on the working plane with brightnesses as indicated below:

Ceiling (above luminaires)	240 footlamberts	Luminaire	
Ceiling (between luminaires)	40 " "	90° to side panel	240 footlamberts
Wall (above bookcase)	15 " "	45° to length (bottom)	240 " "
Desk Top	18 " "	45° to width (bottom)	270 " "
		90° to bottom	280 " "

Lighting data submitted by W. C. Macy, Pacific Gas and Electric Company, 445 Sutter Street, San Francisco, California as an illustration of good lighting practice and to aid in the design of similar installations.

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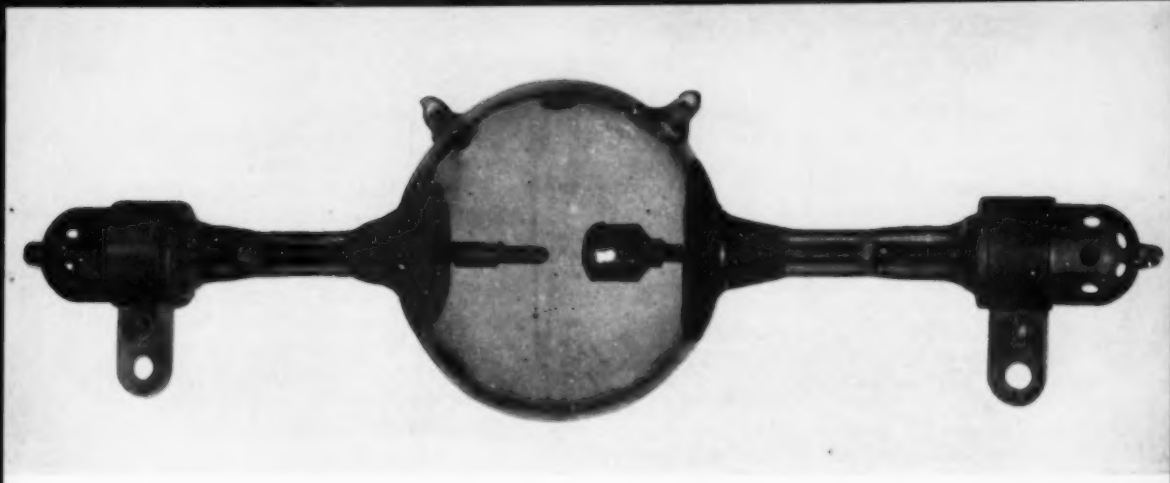

Color Corrected Compact Mercury Lamps For Motion Picture Studio Lighting

AT A MEETING of the Hollywood Section of the Society of Motion Picture Engineers on November 15th, Mr. Richard Blount of the Lamp Department, General Electric Company, described the development by his company of a unique mercury lamp and operating equipment which have been specially designed for use on direct current at standard voltages for the lighting of motion picture studios.

The lamp itself (above) has substantially the same operating characteristics as the lamp developed[1] during and immediately following the war by the British-Thomson-Houston Company in England, but differs markedly in its design, construction, and performance. The new design has resulted in a quality of quartz bulb which is not only much stronger than has been possible heretofore, but also of an optical quality which insures effective utilization of the compact source by the lens and reflector systems with which such sources are to be used. The perfected construction employs a radically new type of seal which makes much higher starting and operating currents feasible. Solid tungsten rods extend through the quartz directly from the terminals to the electrodes. Thus, the maximum practicable wattage of lamps designed for operation on standard voltages has been raised and the warm-up time reduced to only a few minutes.

The lamp demonstrated to the motion picture industry is designed to operate at approximately 5000 watts. It is in a bulb less than four inches in diameter and, unlike the familiar mercury lamps, has a discharge path of only 10 mm. This results in an effective light source area of approximately 50 sq mm as compared with 875 sq mm for the

Lamp Housing. A developmental assembly including the lamp and pulse starting equipment mounted in a typical fresnel lens type of lighting fixture. The white porcelain enameled sphere is helpful in shortening warm-up time and increases efficiency.

[1] "New Developments in Mercury Lamps for Studio Lighting," by F. E. Carlson, Journal Society of Motion Picture Engineers, Vol. 50, Feb., 1948.

5-kw tungsten-filament lamp in the eight-inch diameter bulb used for motion picture studio lighting. The overall length of the 5-kw mercury lamp is 12½ inches, and it may therefore be used in housings of the present size. It is expected that new fresnel lenses will be designed to take full advantage of the new compact light source. However, even when used with the fresnel lens currently available for the 5-kw tungsten-filament lamp, the 5-kw compact-source produces about twice the maximum beam candlepower of the popular "inky."

The third important new element is the associated equipment which is entirely automatic in operation and consists of an unusual resistance ballast and a pulsing system for starting at standard studio voltages, as well as instant re-starting without cooling the lamp. Thus, the lamp may be turned on and off with the same ease as a filament lamp. In order to reduce the run-up time to operating pressure, without resorting to resistance-changing switches, a resistance ballast of silicon carbide has been specially designed which first delivers a high value of current and then as the lamp warms up, automatically reduces the current until the lamp operates at its rated power input. This resistance ballast is small enough and sufficiently light in weight so that it could be built into the lamp housing and, in this event, be a source of radiation which could further reduce the three- to five-minute warm-up interval. Since the pulsing system for starting has already been mounted on the lamp housing, such a move would make the rigging and lighting of movie sets with such lamps almost as simple as it is with filament lamps.

While mercury lamps have long been known for their high degree of photographic effectiveness, the color of the light has limited their use to black-and-white films. Color correction through the use of additional metallic vapors, such as cadmium, zinc, etc., has been possible but at considerable loss in efficiency of light output. In the new lamps color correction is obtained by means of metallic vapors in the discharge at considerably higher efficiency than heretofore — of the order of 50 lumens per watt for the 5000-watt size. Preliminary tests show that, with only slight filter correction, the modified color is acceptable for color motion picture films matched to daylight.

This new type of light source for motion picture studios, the first to be introduced in more than twenty years, combines the high light output and beam candlepowers of the carbon arc with the simplicity and reliability of operation and the cleanliness and quietness of filament lamps.

Lamps and equipment are now undergoing field tests in the studios of the industry.

What can be done with a rough basement area is demonstrated in the transformation of a boiler room into an attractive classroom at the Yantacaw School, Nutley, N. J.

BEFORE

Inadequate window space, low ceilings and a large main steam line across the ceiling presented major problems; lesser ones were rough walls, cement floor, exposed radiators and plumbing.

AFTER

A well planned reconstruction program including fabron walls, asphalt tile floors, enlarged windows and fluorescent lighting created this useful, well lighted classroom. Some 45 Miller fluorescent units in two such rooms furnish an average illumination level of 50 footcandles.

Recommended Practice of Daylighting

Prepared by the Daylighting Committee of the Illuminating Engineering Society*

In our modern world, windows ser e a multitude of purposes. Windows have a history almost as long as that of shelter itself. In ancient times, crude huts had openings in the roof to let lig'it in and to permit smoke to escape. That humble aperture in the roof has, through the centuries, expanded and developed into modern fenestration.

The proper use of fenestration, with the resultant entrance of more daylight, involves an understanding of light and lighting. This is important to present day civilization, with its comp!exity of visual tasks, which virtually demands an environment that will pro/ide good seeing.

Many persons engaged in visual w>rk have imperfect vision. Today, with new materials, construction methods, and techniques, fenestration design is meeting the challenge of our present seeing requirements. Through engineered daylighting, daylight as a source of light is both an economical and a practical means for improving both lighting and seeing.

Foreword

The first I.E.S. Committee on Natural Lighting was appointed in 1924 to study and develop the theory and practice of daylight utilization. That committee sponsored numerous studies and papers on the control and design of natural lighting. In 1945, the committee was renamed Committee on Daylighting and was commissioned "to promote and guide research in Daylighting, develop improved means for utilization thereof, and report thereon." One of their assignments was to prepare a Recommended Practice of Daylighting.

This Recommended Practice is the fifth draft of the Committee's report. The data contained therein is almost entirely from previously published material. It was compiled by a Sub-Committee† assisted by B. F. Greene, Lighting Consultant. The main text comprises the recommendations; design information needed for calculations is presented in six appendices; and the report is concluded by a comprehensive bibliography of over two hundred references.

DAYLIGHTING COMMITTEE

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*Approved by the I.E.S. Council September, 1949.

1. Introduction

1.1—*General* **(a)** Natural lighting is an important part of the design of a building. The fenestration** must therefore be planned in position, area, and dimensions as carefully as any other part of the building.

(b) This, the first Recommended Practice of Daylighting, presents data and recommendations for utilizing daylight effectively. Included are recommendations for daylighting of schools, offices, factories, and homes, expanding daylighting data given in other Illuminating Engineering Society Recommended Practices. (142, 172, 173, 176, 191)*** Although not specifically mentioned, the general

**Fenestration refers to any opening or arrangement of openings (normally filled with media for control) for the admission of daylight. For definitions of other nomenclature see Appendix A.

***In this report numbers in parentheses indicate reference in the bibliography, pp. 137 to 139.

TABLE I.—Equivalent Sky Brightness, Average Overcast Day (48-52)

Latitude	Equivalent Sky Brightness (Footlamberts)								
Date	December 21			March, September 21			June 21		
Hour	8 AM 4 PM	10 AM 2 PM	Noon	8 AM 4 PM	10 AM 2 PM	Noon	8 AM 4 PM	10 AM 2 PM	Noon
30°N	400	1000	1200	900	1800	2400	1300	2450	4200
34°N	350	800	1000	850	1700	2100	1300	2400	3700
38°N	300	700	900	800	1500	1800	1300	2400	3500
42°N	200	600	800	750	1400	1700	1300	2300	3000
46°N	100	500	700	700	1200	1600	1300	2200	2800

methods and principles described herein can be applied to the daylighting of all types of buildings; for example, hospitals, museums, gymnasiums, etc.

(c) All data presented herein are based on the application of information available from previously reported studies. [See pages 000 to 000 for a bibliography of papers pertaining to this subject.]

1.2—Scope **(a)** In his development through the ages, man has been dependent largely upon daylighting for the performance of all visual tasks. As a result, the human eye is adapted to an optical environment produced by daylight. Today, daylighting is one of the most effective means of obtaining good lighting. By the proper utilization of daylight, lighting meeting all the requirements for good seeing conditions can be obtained throughout a room.

(b) The window as a source of light can be treated as any other type of light source; and the requirements for good lighting—adequate illumination, proper distribution, and freedom from high brightness variations (ratios)—applied. Similarly, the factors affecting lighting design (window efficiency, maintenance factors, effect of different reflectances of interior surfaces, etc.) should be considered in the design of daylighting.

(c) Generally speaking, the chief difference between the methods of designing for daylighting and for artificial lighting is that the amount of daylighting varies, and it is usually necessary to provide artificial lighting systems for the time of day when the values fall below practical levels.

1.3—Criteria for Seeing **(a)** The degree of seeing depends on the amount of light reaching the eye from the task and the surroundings. All other things being equal, the ability to distinguish fine detail and small brightness contrast is increased with higher illumination. It has been shown also that speed of vision increases with the increase of illumination. (4,7,17,24) The amount of light required for different visual tasks is shown in Table VI.

(b) A factor which has great importance in seeing comfort is glare (8, 23). Glare results from excessive brightness ratios in the visual field. The source of glare can be either the light source, or its reflection from a shiny surface.

(c) The criteria for daylighting depend on the type of work being done in the area in question. There are, however, certain general criteria regarding the quantity and quality of illumination which apply to all seeing conditions. These refer to the amount and distribution of illumination and the brightness ratios between the visual work and the immediate and peripheral surroundings.

(d) A definite appraisal of these criteria for different visual tasks is discussed in Sections 4, 5, and 6.

2. Daylighting Design Principles (Sky)

2.1—General—Openings in walls and ceiling afford a means of obtaining a portion of the available outdoor light within a room. The outside illumination varies with time and weather conditions, while the portion of the light entering a room depends upon the size, the position, and the light transmission of the medium in the opening. Each of these factors can be considered separately and methods devised for predetermining daylight illumination values. Using the methods outlined in Appendix E, fenestration meeting desired lighting requirements can be planned.

TABLE II.—Clear Day*
Equivalent Sky Brightness (Ft-L). (48-52)

Latitude	December 21					March and September 21					June 21				
	8 AM	10 AM	Noon	2 PM	4 PM	8 AM	10 AM	Noon	2 PM	4 PM	8 AM	10 AM	Noon	2 PM	4 PM
North															
30°N	450	600	600	600	450	700	1050	1050	1000	700	1550	1400	1000	1400	1550
34°N	350	550	550	550	350	800	800	900	800	800	1350	1400	950	1400	1350
38°N	300	550	550	550	300	750	800	900	800	750	1350	1300	950	1300	1350
42°N	250	500	500	500	250	700	750	800	750	700	1300	1300	950	1300	1300
46°N	150	450	500	450	150	700	750	750	750	700	1300	1250	950	1250	1300
South															
30°N	1400	1950	2250	1950	1100	1700	2300	2400	2300	1700	1200	1600	2400	1600	1200
34°N	1100	1900	2200	1900	1100	1700	2650	2900	2650	1700	1350	1650	2300	1650	1350
38°N	900	2200	2200	2200	900	1700	2700	2950	2700	1700	1350	1650	2300	1650	1350
42°N	600	2150	2150	2150	600	1700	2750	2450	2700	1700	1350	2000	2300	2000	1350
46°N	400	1900	2100	1900	400	1700	2700	2900	2750	1700	1350	2100	2700	2100	1350
East															
30°N	1400	1500	1000	700	400	2000	2500	1500	900	700	2400	2650	1400	1000	700
34°N	1300	1400	950	700	400	2400	2600	1600	950	650	2800	2700	1450	1000	700
38°N	1200	1300	900	650	350	2500	2600	1500	900	600	2800	2700	1400	1050	700
42°N	750	1250	850	600	250	2400	2400	1450	900	600	2900	2600	1400	1000	700
46°N	700	1100	800	500	150	2300	2100	1400	700	650	2850	2600	1400	100	700
West															
30°N	400	700	1000	1500	1150	700	900	1500	2500	2000	700	1000	1450	2650	2800
34°N	400	700	950	1400	1350	850	900	1600	2600	2400	700	1050	1400	2700	2800
38°N	350	650	900	1300	1200	800	900	1500	2600	2500	700	1050	1400	2700	2800
42°N	250	600	850	1200	750	600	800	1450	2400	2400	700	1000	1400	2600	2900
46°N	150	500	800	1100	500	800	700	1400	2400	2300	700	1000	1400	2600	2850

*Average values. Direct sunlight excluded.

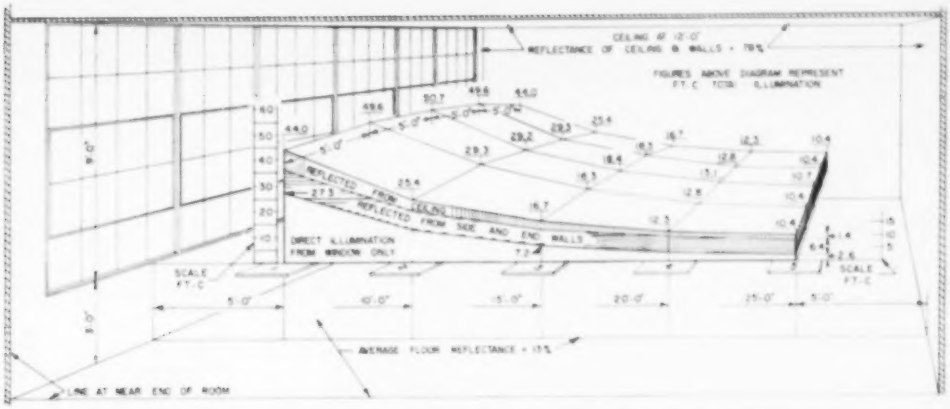

CEILING AT 12'-0"
REFLECTANCE OF CEILING & WALLS = 70%
FIGURES ABOVE DIAGRAM REPRESENT FT-C TOTAL ILLUMINATION
REFLECTED FROM CEILING
REFLECTED FROM SIDE AND END WALLS
DIRECT ILLUMINATION FROM WINDOW ONLY
SCALE FT-C
AVERAGE FLOOR REFLECTANCE = 15%
LINE AT REAR END OF ROOM

Figure 1. Illumination distribution (including reflected light from walls and ceiling), window height 9 feet, sky brightness 315 footlamberts. (Compiled by G. W. Thomas from Ref. 47)

2.2—*Source Brightness*

2.2.1—*General*—**(a)** The primary source of light for daylighting is the sun. The light from the sun is scattered in its passage through the atmosphere over an area called the sky. The relative amount of daylight from the sun and sky depends upon the position of the sun and on the atmospheric conditions. Usually for daylighting studies, two classifications of exterior illumination are considered, namely:

(1) clear day with direct sunlight
(2) overcast day

(b) The average number of cloudy and clear days for different locations in the United States is given in Figs. C-1 and C-2.

(c) Both bright sunshine and overcast sky conditions offer a challenge to the designer of a building in making daylight usable; the daylighting design should satisfy these two conditions. An overcast day requires a fenestration which makes use of all available illumination, whereas clear days normally require the use of some means for controlling the brightness of the direct sunlight in the room. Criteria for designing for sky conditions are given in this section. Sunlight conditions are described in Section 3.

2.2.2—*Overcast Sky Brightness*—The sky brightness and distribution on an overcast day vary with location and time. However, for any particular condition, a single value representing the equivalent sky brightness can be obtained that may be used for design purposes. The average value of the equivalent sky brightness for different latitudes and times is given in Table I. (See Appendix C.)

2.2.3—*Clear Sky Brightness*—The sky brightness on a clear day varies with the position of the sun. (See Figures C-3, C-4, C-5 and C-6.) The equivalent sky brightness varies with different orientations. The average value of the

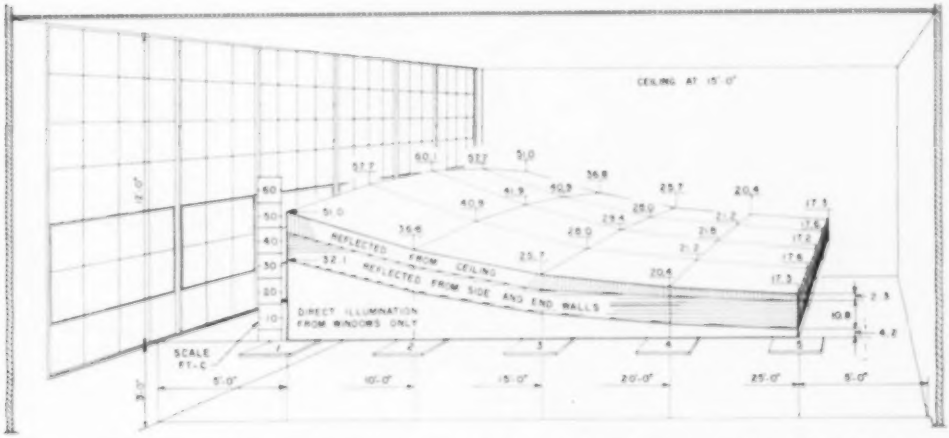


Figure 2. Illuminating distribution (including reflected light from walls and ceiling), window height 12 feet, sky brightness 315 footlamberts. (Compiled by G. W. Thomas from Ref. 47)

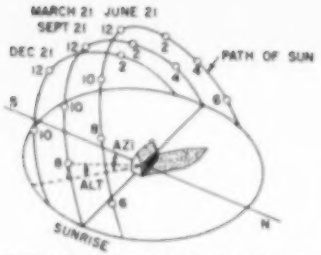


Figure 3. Solar altitude and azimuth, 42° N. latitude.

TABLE III—Average Window Maintenance Factors. Expressed as Percentage of Clean Glass Transmission

	Window Position				
	Office*	Factory**			
	Vertical	Vertical	30° from Vertical	60° from Vertical	Horizontal
Avg. value over 6 mo. period	80%	65%	55%	50%	45%
Value end of 3 mo. period	82	69	62	54	50
Value end of 6 mo. period	73	55	45	39	34

*Typical clean location.
**Typical dirty location.

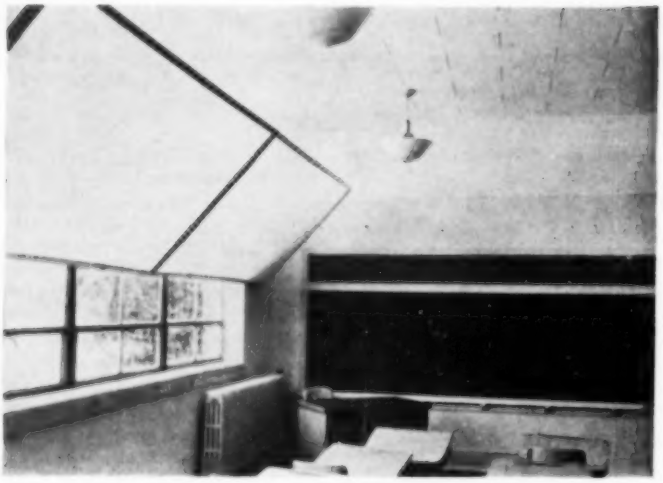


Figure 4. Light diffuser for classroom daylight and glare control.

equivalent sky brightness on clear days for north, east, west, and southern exposures is given in Table II for different latitudes and times. For daylight calculations on clear days, both the clear sky brightness and the direct sunlight must be considered.

2.3—Daylighting Distribution—**(a)** If one makes an opening in an outside ceiling or wall, a certain portion of the outside light is distributed within. For the case of an overcast sky source, mathematical methods have been established which enable the prediction of illumination at any plane and at any point within a room. (See Appendix E.) The illumination distribution on a horizontal plane resulting from two different window heights is shown in Figs. 1 and 2. (47)

(b) The upper part of the fenestration is the most effective portion for lighting the back of the room. As shown in Figs. 1 and 2, the illumina-

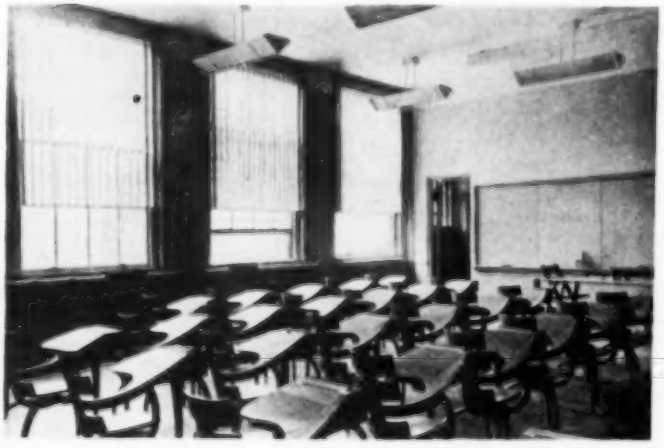
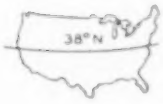


Figure 5. The use of vertical metal louvers for sunlight control in a schoolroom. The louvers are fixed in a frame which is hinged at the top for window cleaning.

TABLE IV.—Solar Altitude and Azimuth for Different Latitudes.

		Date	Solar Time AM: 6 / PM: 6	7 / 5	8 / 4	9 / 3	10 / 2	11 / 1	Noon
	ALTITUDE	June 21	12	24	37	50	63	75	83
		Mar.-Sept. 21	—	13	26	38	49	57	60
		Dec. 21	—	—	12	21	29	35	37
	AZIMUTH	June 21	111	104	99	92	84	67	0
		Mar.-Sept. 21	90	83	74	64	49	28	0
		Dec. 21	—	60	54	44	32	17	0
	ALTITUDE	June 21	13	25	37	50	62	74	79
		Mar.-Sept. 21	—	12	25	36	45	53	56
		Dec. 21	—	—	9	18	26	31	33
	AZIMUTH	June 21	113	106	95	90	78	58	0
		Mar.-Sept. 21	90	82	72	61	46	26	0
		Dec. 21	—	—	54	43	30	16	0
	ALTITUDE	June 21	14	26	37	49	61	71	75
		Mar.-Sept. 21	—	12	23	34	43	50	52
		Dec. 21	—	—	7	16	23	27	28
	AZIMUTH	June 21	109	101	90	83	70	46	0
		Mar.-Sept. 21	90	81	71	58	43	24	0
		Dec. 21	—	—	54	43	30	16	0
	ALTITUDE	June 21	15	27	38	49	60	68	71
		Mar.-Sept. 21	—	11	22	32	40	46	48
		Dec. 21	—	—	4	13	19	23	25
	AZIMUTH	June 21	108	99	89	78	63	39	0
		Mar.-Sept. 21	90	80	69	56	41	22	0
		Dec. 21	—	—	53	42	29	15	0
	ALTITUDE	June 21	17	27	37	48	57	65	67
		Mar.-Sept. 21	—	10	20	30	37	42	44
		Dec. 21	—	—	2	10	15	20	21
	AZIMUTH	June 21	107	97	88	74	58	34	0
		Mar.-Sept. 21	90	79	67	54	39	21	0
		Dec. 21	—	—	52	41	28	14	0
	ALTITUDE	June 21	17	27	37	47	56	63	65
		Mar.-Sept. 21	—	10	20	29	36	40	42
		Dec. 21	—	—	1	8	14	17	19
	AZIMUTH	June 21	106	95	85	72	55	31	0
		Mar.-Sept. 21	90	79	67	53	38	20	0
		Dec. 21	—	—	52	41	28	14	0

tion towards the back of the room from a window with clear glass 12 feet high and a sill height of three feet is almost twice that from a window of the same width with a height of nine feet. It is advisable, therefore, to locate the top of the opening as high as possible; *i.e.*, close to the ceiling.

2.4—Glass The effect of the placement of glass or glass block in the window opening is to reduce the brightness of the source. The amount of the brightness and illumination reductions depends on the type of material used. The transmission factors for different types of glass appear in Appendix F.

2.5—Effect of Walls and Ceilings **(a)** To obtain the maximum task lighting it is important that walls, ceilings, and all other reflecting surfaces in the field of view be finished in light colors with a flat or egg-shell finish.

Figure 6. Example showing the use of venetian blinds as a means of sunlight control.

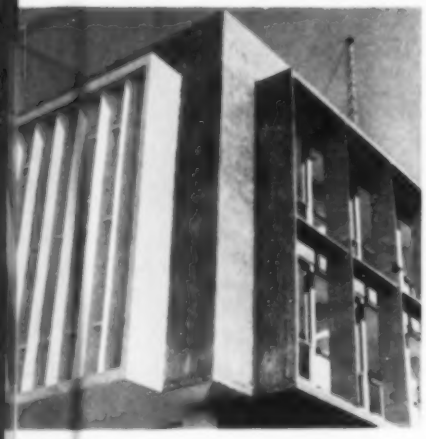


Figure 7. (Above) Use of horizontal overhang over clear vision panel. (Figure 8. (Below) Use of large horizontal and vertical precast concrete louvers for sunlight control. (Photo M. M. M. Roberto, Architects, Rio de Janeiro, Brazil.)

In addition to reducing brightness ratios in the field of view, light colors used inside and out result in a more uniform illumination distribution (Figs. 1 and 2).

(b) The reflectance of outside surfaces is important in daylighting design. When windows are mounted along side walls, the daylight is reflected from the ground to the ceiling and then to the working plane. The light from outside surfaces also is reflected to the walls, which in turn redirect the light to the working surfaces.

(c) The component of illumination from ceilings and walls increases the daylight values within a room and is, in general, proportional to the window area and the interior and exterior reflectances. The amount of this increase is about the same for all locations within the room. (84) The percentage of the reflected to the direct component of daylighting is therefore greater in the rear of the room.

2.6—Obstructions—**(a)** Methods for predicting illumination and brightness distribution throughout a room, given in Appendix E, are based on an unobstructed view of the sky. As this condition does not often exist, the effect of different arrangements of obstructions must be considered.

(b) The amount that an obstruction reduces the daylighting within a room can be obtained by using the applicable mathematical relations and the principle of superposition (Appendix E). The daylight illumination with an obstruction in the field of view depends upon the size, location, and reflectance of the obstruction. For example, if at a point in the room an outside obstruction covers the entire field of view, when looking out of the window, then the illumination at that point is proportional to the equivalent sky brightness times the reflectance of the obstruction.

(c) For multi-story buildings see Section 6.9.

2.7—Maintenance Factors—The accumulation of dirt on window surfaces results in decreasing the daylight illumination. The amount of the reduction varies with the location, the angle at which the glass is mounted, and the cleaning schedule. Average values of maintenance factors for typical office and factory locations, over a six months' cleaning schedule and at the end of a three-month and a six-month period are given in Table III. If it is known that the windows are to be used in a particularly clean or particularly dirty location, values other than those shown in Table III should be used. (22, 116, 181, 203, 299)

3. Design Principles (Sun)

3.1—General—**(a)** There are many different components of solar energy. The number and amount of each can be obtained from solar radiation curves. (57)

(b) The amount of solar heat and other components of solar energy depends on the position of the sun in the sky. For clear sky conditions, the factor of greatest importance is the position of the sun in relation to the room in question.

3.2—Sun's Path—The position of the sun can be expressed in terms of two angles. One of these is altitude, the vertical angle of the sun above the horizon. The second is azimuth, the horizontal angle of the sun from the due south line (Fig. 3). The solar altitude and azimuth for different latitudes is shown in Table IV. By a geometrical combination of solar altitudes and azimuths, the sunlight penetration into a room can be determined with clear glazing (Appendix D).

TABLE V.—Average Solar Illumination as a Function of Altitude (50, 51, 57)

Latitude		Illumination (Footcandles)								
		December 21			March, Sept. 21			June 21		
Date Hour	Plane	8 AM 4 PM	10 AM 2 PM	Noon	8 AM 4 PM	10 AM 2 PM	Noon	8 AM 4 PM	10 AM 2 PM	Noon
30° N	Perp.*	4200	7000	7700	6400	8300	8600	7700	8600	8300
	Horiz.	700	3400	4400	2600	5400	7000	6400	7200	8500
34° N	Perp.*	3100	6500	7100	6300	8100	8400	7600	8600	8900
	Horiz.	800	2700	3700	2800	5600	6700	6700	7100	8400
38° N	Perp.*	2500	6000	6900	6100	8000	8300	7600	8500	8900
	Horiz.	900	2000	3000	2100	5400	6200	6400	7000	8300
42° N	Perp.*	2000	5500	6400	6000	7800	8200	7600	8400	8800
	Horiz.	100	1600	2700	2000	4800	5800	6700	6800	7900
46° N	Perp.*	500	4500	5800	5800	7600	8100	7600	8100	8800
	Horiz.	.....	1000	1800	1800	4400	5500	6400	6700	7400

*Perpendicular to sun's rays.

Figure 9. Building arrangement to permit bilateral and clerestory lighting.

3.3—*Solar Illumination* —The illumination from the sun is high relative to indoor illumination levels. Solar illumination for different times and conditions is shown in Table V. From this table, it will be noted that the solar illumination depends on the position of the sun, and is of the order of several thousand footcandles.

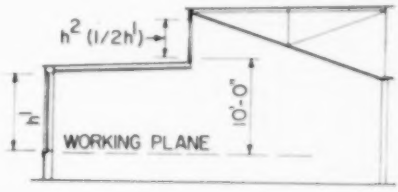
3.4—*Orientation* — **(a)** The desired amount and penetration of sunlight is an important factor in the determination of room or building orientation and proportion. In addition to the considerations of building usage and street arrangements, other factors affecting building orientation are: prevailing winds, natural ventilation requirements, and lot size. Each building condition presents separate problems. However, certain general rules can be stated regarding preferred conditions.

(b) In northern latitudes of the United States, wherever possible, consideration should be given to orienting the fenestration in a southerly direction in order to obtain the maximum amount of light with simple and effective methods of sunlight control. In southern locations of the United States, wherever possible, northerly exposures should be considered in order to limit the solar heating. When the sun is in the field of view, some means of brightness control should be utilized.

3.5—*Sunlight Control* — Brightness conditions resulting from direct sunlight in rooms on a clear day may be well above the optimum required for good seeing. It is important, therefore, that some method of sunlight control be used. The control can be either fixed or variable, located outside or within the room. Some methods of sunlight control are as follows:

Shades—When mounted in front of windows within a room, shades either diffuse or exclude sunlight. For maximum effectiveness, the shades should be light in color and normally mounted at the center of the window. Since the light that enters at the top of the window glazed with clear or diffusing media is most effective in lighting the far side of the room, consideration should be given to installing two roller shades at the center of such a window, arranged so that they can be pulled up or down to take care of different sunlight conditions.

Diffusing Screens—Diffusing screens mounted at the center of the window, and arranged to shield the upper part



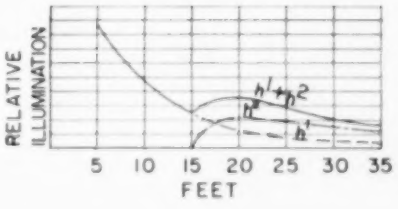


Figure 10. (Bottom Left) Example of a bilateral window arrangement with suitable shading. Figure 11. (Bottom Right) Example of window arrangement with clerestory lighting. Figure 12. (Top Right) Illumination distribution from sidewall and clerestory windows (windows 30 feet long, no reflections).

Figure 13. (Left) Example of window arrangement extending to front of room with minimum obstruction. Figure 14. (Right) Interior of a schoolroom illustrating the use of glass block with a clear glass vision strip.

of the window are a means for reducing the brightness of direct sunlight. An effective method of obtaining diffused lighting throughout the room is to mount the screens at an angle of 45 degrees from the window, which will then reflect a portion of the incident light to the ceiling (Fig. 4). A recommended transmission factor for these screens is about 60 per cent. (145)

Louvers or Baffles — Louvers or baffles located in front of the window within a room are a means for eliminating the high brightness of the sun in the field of view and for redistributing the incident light. Louvers or baffles should be finished in a light color and arranged to shield the source from normal viewing angles (Fig. 5).

Venetian Blinds — Venetian blinds are another means for eliminating the high brightness of the sun in the field of view. They should be mounted above the head of the window opening so as not to reduce the effectiveness of the upper part of the window area. The blind should be finished in a light color so that the daylight will be redirected to the ceiling and back into the room (Fig. 6).

Light Controlling Glass — Certain types of prismatic glass and glass block have light directional properties by which light from the sun is redirected above the horizontal to the ceiling and upper walls of the room. This serves to increase the illumination in the back of the room (see Section 2.5 of Appendix E) and to reduce the brightness of the direct sunlight when viewed from a position within the room. (121, 159) Whenever light directional glass or glass block is used, it should be located above head height so as not to cause excessive brightness when looking at the glass. The portion of the fenestration below the light directional panel may be a clear vision strip or light diffusing glass or glass block (Fig. 7).

Fixed Horizontal and Vertical Overhangs — Fixed projections can be designed to shade a window from direct sunlight during certain periods of time. Consideration should be given to mounting these overhangs slightly above and to the side of the window in order to obtain the desired shading without materially reducing the effectiveness of the window in admitting skylight to the room. Horizontal projections are more effective on southerly exposures, while on eastern and western exposures combinations of horizontal and vertical projections should be considered.

Fixed horizontal and vertical projections located outside the window are an effective means for shading the

TABLE VI—Lighting Levels at the Work (Maintained in Service)

Locations	Current Recommended Practice* Minimum Footcandles
Classrooms — on desks and chalkboards	30
Study hall, lecture rooms, art rooms, offices, libraries, shops, and laboratories	30
Classrooms for partially seeing pupils and those requiring lip reading — on desks and chalkboards	50
Drafting rooms, typing rooms, sewing rooms	50
Reception rooms, gymnasium, continuing prod	20
Auditoriums (not for study), cafeterias, locker rooms, washrooms, corridors containing lockers, stairways	10
Store corridors and store rooms	5

*Obtained from daylighting, artificial lighting, or combinations of both.

Figure 15. (Left) Illustrating the use of glass block and insert windows for vision and ventilation. Figure 16. (Right) Example of school daylighting with the window sill height determined by the radiator arrangement.

Figure 17. Daylighting in a school gymnasium with the fenestration arranged on four sides and the sill high above the floor.

room from direct sunlight and heat, and require little maintenance (Fig. 8). (See Section 2 of Appendix D for design equations.)

4. Daylighting in Schools

4.1—*General* **(a)** Close visual tasks are continually being performed in schools and it is important that the requisites for good lighting be fulfilled. Investigations of seeing conditions in the elementary classroom have indicated that improper lighting has resulted in far-reaching effects in the general health of school children. (9, 153)

(b) In the design of a lighting system, it is impossible to isolate the light source from the lighting system. In classroom design the effectiveness of the light source on both clear and cloudy days must be considered in relation to the room interior. The factors which must be taken into account and integrated in the daylighting design for schools are as follows:

(1) Orientation
(2) Fenestration
(3) Sunlight control
(4) Interior decoration
(5) Room and equipment arrangement
(6) Maintenance
(7) Type of work performed

4.2—*Requirements* A basic requirement for good school daylighting is an adequate level of illumination, well-distributed with no excessive brightness ratios for areas of appreciable size within the field of view from normal working positions. The limiting brightness ratios for areas of appreciable size recommended in school

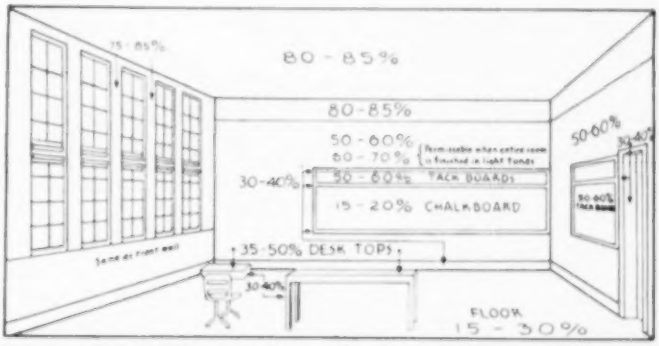


Figure 18. High reflectance, non-glossy surfaces increase illumination and decrease brightness ratios.

Figure 19. (Left) Seating arrangement in relation to window wall. Figure 20. (Right) Classroom seating arrangement to avoid high brightness ratios in the field of view.

Figure 21. Example of the use of clear glass windows in the office section of an industrial building.

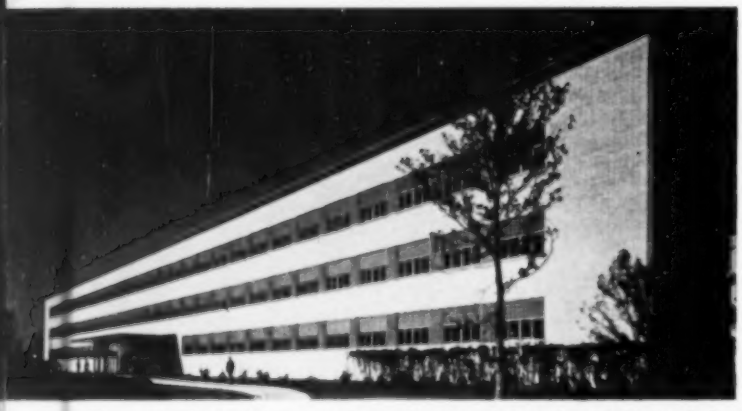


Figure 22. Illustrating the use of a combination of clear glass windows and glass block in an office building.

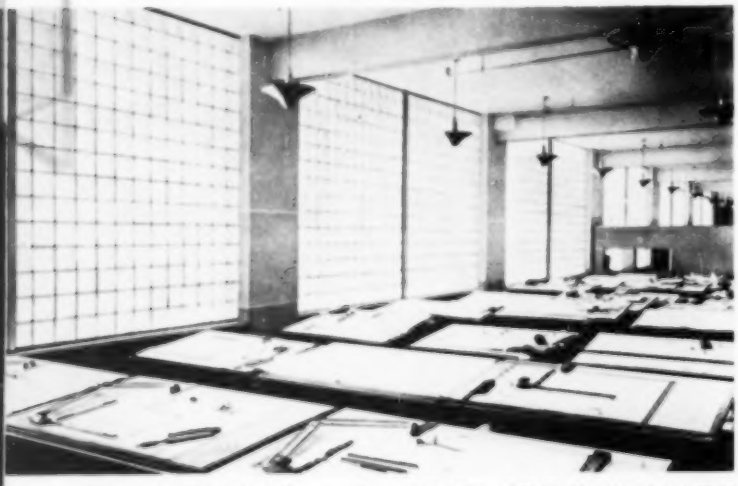


Figure 23. Illustrating the use of a combination of light directional and light diffusing glass block.

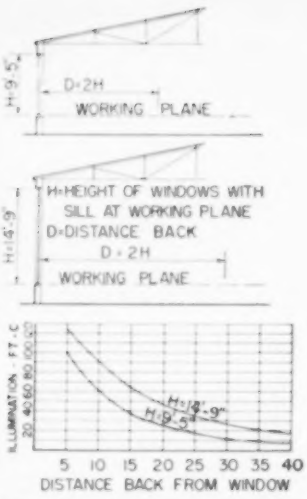


Figure 24. Illumination distribution from sidewall windows assuming no reflection, clean glass, and 1000 footlamberts uniform sky brightness.

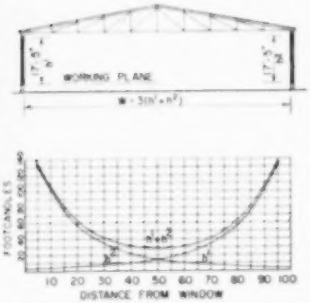


Figure 25. Illumination distribution from sidewall windows assuming no reflection, clean glass, and 1000 footlamberts uniform sky brightness.

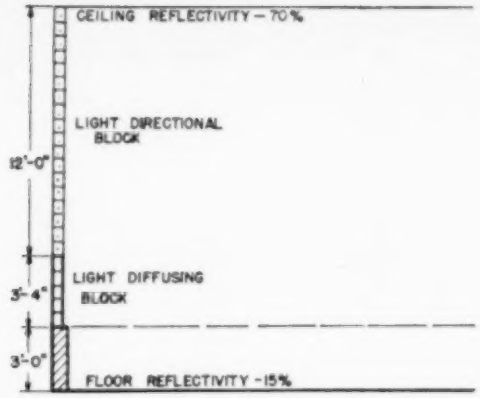
rooms used for educational purposes are as follows: (142)

(1) between the seeing task and immediately adjacent surfaces, such as between task and desk top, with the task the brighter surface — ratio of 1 to ⅓

(2) between the task and the more remote darker surfaces in the surrounding field, such as between task and floor, and task and wall beneath the window — ratio of 1 to 1/10.

(3) between the task and the more remote brighter surrounding surfaces in the visual field, such as between task and ceiling — ratio of 1 to 10.

(4) between windows and surrounding surfaces adjacent to them in the visual field — ratio of 20 to 1.



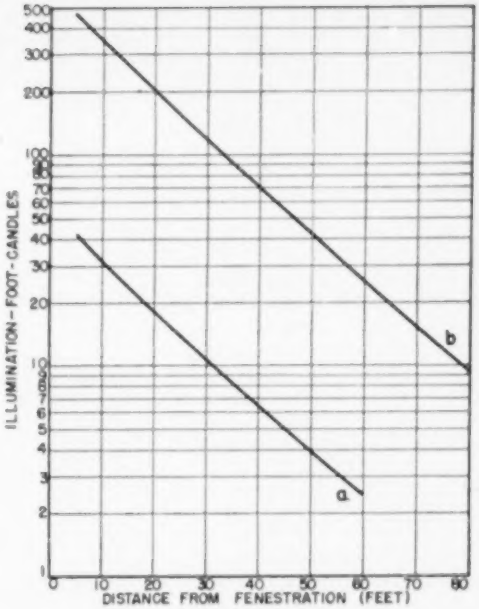
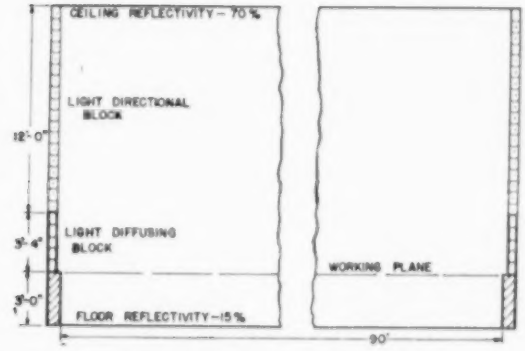


Figure 26. Unilateral Daylighting—Glass Block
(a) (Above) overcast sky, equivalent sky brightness 1000 ft-L
(b) (Right) sun and clear sky, south exposure, 40° N. latitude, equinox, 10 A.M. or 2 P.M.



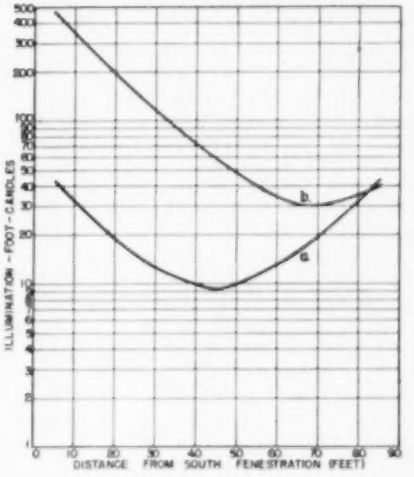


Figure 27. Bilateral Daylighting—Glass Block
(a) (Above) overcast sky, equivalent sky brightness 1000 ft-L
(b) (Right) sun and clear sky, south and north exposures, 40° N. latitude, equinox, 10 A.M. or 2 P.M.

The recommended illumination levels within the school vary with the usage of the room. The illumination levels listed in the *American Standard Practice for School Lighting* are shown in Table VI. (142)

4.3—*Orientation*—(a) The orientation of a building is generally determined by local conditions. Some general considerations are: When solar heat is not a factor, orienting buildings in a southerly direction to obtain maximum light is desirable. When it is desired to avoid solar heat or direct sunlight, in the United States and Canada windows should be faced in a northerly direction.

(b) Building orientation influences fenestration design. For orientations other than north, some means should be provided for sunlight control.

4.4—*Fenestration*

4.4.1—*General*—(a) Fenestration must be correlated with the room arrangement. Openings should be located with a view toward providing suitable lighting and the seating arrangements should be such that all windows are out of the field of view for normal working conditions. (Paragraph 4.8)

(b) Since school design is generally limited by the building site, unilateral daylighting of classrooms is widely used. When this is done, it is recommended that the glass areas be as continuous as possible and preferably extend the full length of the room.

Whenever the building structure requires piers, such piers should be kept to a minimum. Where deep reveals are necessary they should be splayed.

(c) Where building sites and land costs permit, consideration should be given to the use of bilateral lighting in classrooms. The advantages of lighting from opposite walls are greater permissible room width or more uniform and higher levels of illumination (Figs. 9 and 10).

(d) For single story structures, consideration should be given to the use of clerestory lighting. The clerestory may face the same direction as the sidewall fenestration or may be opposite (Figs. 11 and 12). Where the design permits but one choice, the preferred arrangement from the point of view of light distribution is to face the clerestory in the same direction as the principal fenestration. The use of a clerestory permits the utilization of wider rooms with good daylighting.

4.4.2—*Fenestration Arrangement*—**(a)** Since the upper part of a window glazed with clear or diffusing media is more effective in lighting the back of the room, the window head should be as high as possible, close to the ceiling (Fig. 13). The height of the window above the floor is related to the room width, and for the recommended uniformity of illumination the effective width of the room should be limited to approximately twice the distance from the floor to the top of the window.

(b) Light directional panels should start not less than six feet above the floor and should extend to the ceiling (Fig. 14). In conjunction with the light directional panel, a vision strip placed in the lower part of the opening may be used to permit vision to the outside. Suitable provision should be made to control the brightness through the vision strip (Fig. 15).

4.4.3—*Percentage Area*—The ratio of the glass area to the floor area gives an indication of the amount of daylight within a room. For purposes of design, a minimum of 20 per cent of glass to floor area should be used where unilateral lighting utilizing clear glass is employed. Where there are many obstructions in the field of view, or where glass or glass block having a lower *transmission factor* is used, this ratio must be increased in order to obtain corresponding illumination levels (Appendix F).

4.4.4—*Sill Location*—The amount of daylight from the lower part of the window has little effect on the daylight distribution in the room. The sill height can thus be determined on the basis of such factors as desired field of view, the room use, disciplinary problems, and safety (Figs. 16 and 17).

4.5—*Glass*—(a) Of the various types of flat glass, clear glass normally is used for school room windows, although glare-reducing and light-diffusing glass may be used if adequate brightness control is provided.

(b) Glass block may be used for schools. In classrooms with sun exposure, light-directional block should be installed above the line of vision. In other rooms, light-directional or other types of block may be used, the selection being such that the light diffusion does not cause uncomfortable brightness in the field of view.

4.6—*Sunlight Control*—In order to reduce excessive brightness differences, some means of sunlight control should be provided whenever the sun is in the field of view. This is particularly important when the windows are continuous and extend to the front of the room. Section 3.5 of this report discusses many different fixed and variable types of sunlight controls, such as light-controlling glass, light-directional glass block, fixed horizontal and vertical projections, louvers, baffles, venetian blinds, shades, screens.

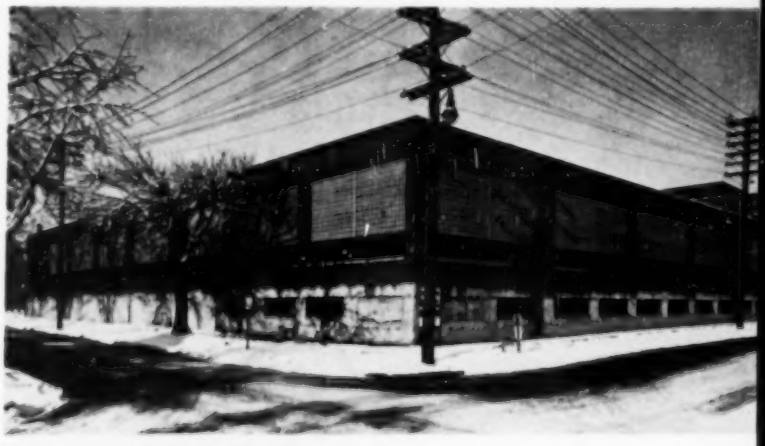


Figure 28. (Left) Large sidewall window areas extending high above the working plane provide adequate natural lighting well into the room. Figure 29. (Above) Illustrating the use of clear glass windows and light directional glass block in a factory building.

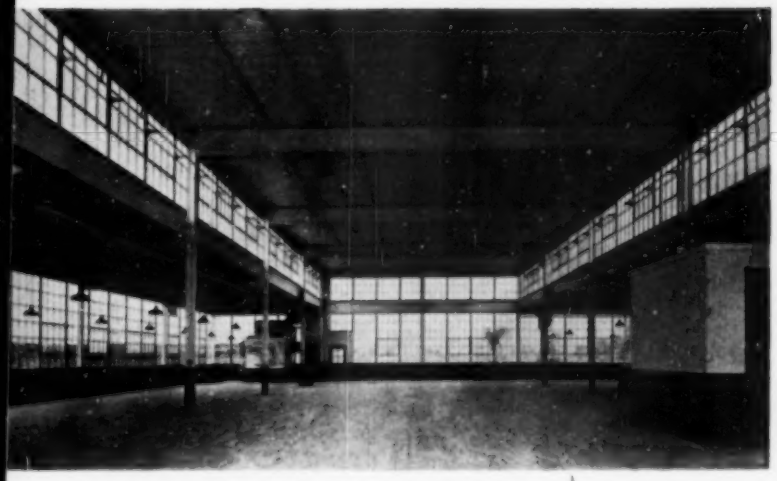


Figure 30. (Above) Uniform illumination obtained by the use of overhead daylighting. Figure 31. (Left) Daylighting obtained by the use of monitors, with large glass areas in the side wall windows.

4.7—*Interior Decoration* — Walls and ceilings should be finished in light colors having a flat or egg-shell finish. Recommended reflectances for ceilings are 80-85 per cent, and for walls 50-60 per cent. Desks and table tops should have a flat finish with a reflectance between 35-50 per cent. Floors should have a reflectance between 15-30 per cent and suitable maintenance procedures to avoid darkening. Consideration should be given to covering dark chalk boards with light-colored shades or panels when the board is not in use or to the use of lighter colored chalk boards, to improve brightness ratios (Fig. 18).

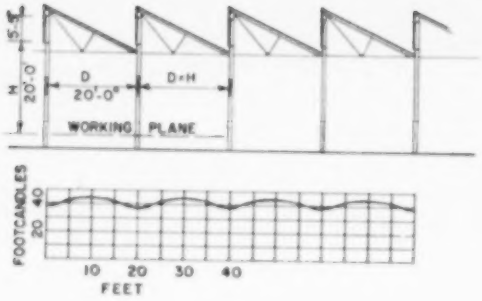
4.8—*Classroom Arrangement* — Desks should be arranged to make use of available light where it is most needed, and avoid having the outdoor brightnesses in the normal field of view of the pupil. It is preferable to have the desks arranged so that the angle subtended at any desk by a line drawn between the desk and a point in the front left corner of the room and a line perpendicular to the desk is 50 degrees or more (Figs. 19 and 20). (9, 145)

4.9—*Maintenance* — Definite maintenance schedules should be established for cleaning windows and other light controlling media. The rate of light loss depends upon rate of dirt accumulation, which in turn depends upon the building location, atmospheric conditions, etc. In general, the windows and other light controlling media should be cleaned at least twice a year. (116) (See Table III.)

5. Daylighting in Offices

5.1—*General* — **(a)** As most office work is done during the daylight hours, it is particularly advantageous to design the fenestration so as to obtain the maximum use of daylight. The requirements for proper daylighting in offices are similar to those enumerated in Section 4, "Daylighting in Schools", namely, adequate illumination properly distributed and freedom from high brightness ratios.

Figure 32. Illustrating the use of glass block in monitors.



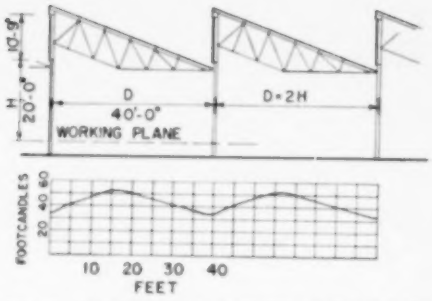
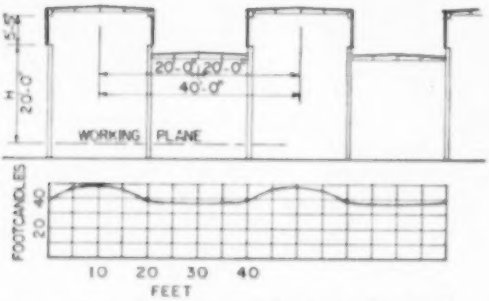


Figure 33. (Upper Left) Illumination distribution from sawtooth windows assuming no reflection, clean glass, and 1000 footlamberts uniform sky brightness. Figure 34. (Upper Right) Illumination distribution from sawtooth windows assuming no reflection, clean glass, and 1000 footlamberts uniform sky brightness.



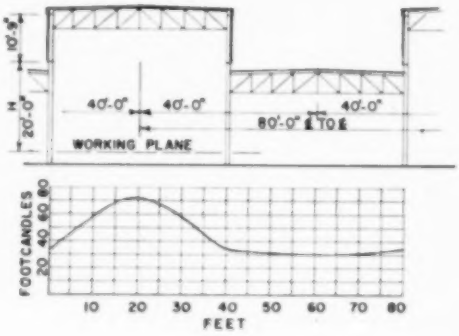
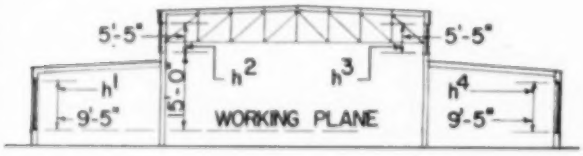


Figure 35. (Above) Illumination distribution from monitor windows. Center line spacing equals twice mounting height. No reflection, clean glass, and 1000 footlamberts uniform sky brightness. Figure 36. (Right) Illumination distribution from monitor windows. Center line spacing equals four times mounting height. No reflection, clean glass, and 1000 footlamberts uniform sky brightness.



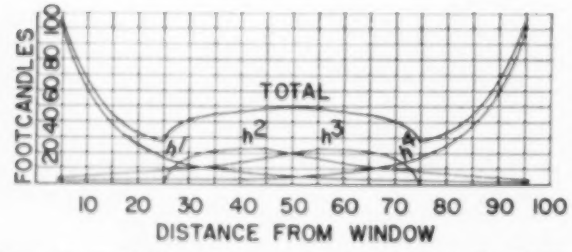


Figure 37. Illumination distribution from sidewall plus monitor windows assuming no reflection, clean glass, and 1000 footlamberts uniform sky brightness.

(b) In the daylighting of offices, it is necessary to take into consideration the building orientation, window type, size, and location, and the treatment of the room interior.

5.2—*Fenestration*

5.2.1—*General*—**(a)** Where the room design is limited to locating the fenestration along one wall, it should be as continuous as possible with the piers and mullions kept to a minimum (Fig. 21).

(b) For deep rooms, consideration should be given to the admission of daylight through more than one wall. The illumination distribution from this arrangement permits effective lighting of greater room widths.

5.2.2—*Location*—The head of the window should be as high as possible, close to the ceiling. The effective working distance back from the window is equal to about twice the window height. (97)

Figure 38. Example of monitor construction.

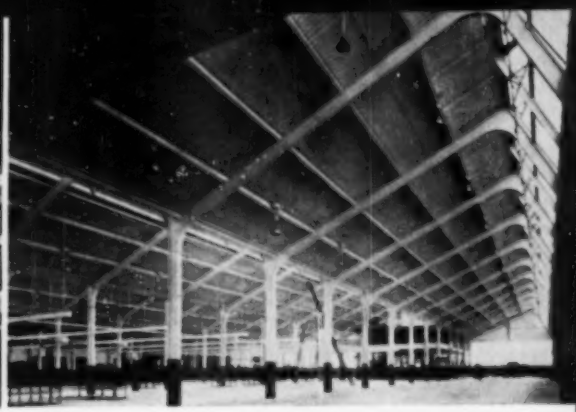


Figure 39. Daylighting by sawtooth construction

Where light directional panels are used, they should extend from about six feet above the floor to the ceiling. A vision strip placed in the lower part of the opening may be used to provide vision to the outside (Fig. 22). Insert windows may also be used for vision and ventilation.

5.2.3—*Percentage area*—For general office areas, the percentage of the window to the floor area should be at least equal to 20 per cent. Where there are many obstructions in the field of view or where glass having a transmittance less than clear glass is used, it may be desirable to increase the ratio of window to floor area.

5.2.4—*Sill Location*—Since the amount of light from the lower part of the window has little effect on the daylight distribution, the sill height can be determined on the basis of such factors as radiator heights, desirable field of view, etc.

5.3—***Glass***—Of the various types of flat glass used in windows, clear glass is normally preferred. Where glass block is used in offices with sun exposures they should be of the light directional type above the line of vision. In other rooms, light directional or other types of block may be used, the selection being such that they do not cause uncomfortable brightnesses in the field of view (Fig. 23).

5.4—***Sunlight Control***—In order to prevent high brightness ratios in the field of view, some method of sunlight control such as shades, blinds, light controlling glass, light directional glass block, etc. should be used.

5.5—***Interior Decoration***—**(a)** Walls and ceilings should be finished in light colors having a flat or egg shell finish. Recommended reflectances for ceilings are 75-85 per cent and for walls 50-60 per cent. Desks and table tops should have a non-glossy light finish with between 30-35 per cent reflectance. Floors should have a reflectance of about 20-30 per cent.

(b) Whenever draperies are used, they should be arranged at the side of the window so as not to limit the daylight greatly.

5.6—***Room Arrangement***—Desks and other working surfaces should be arranged so that the person performing the visual task is neither facing a window nor working in his own shadow.

5.7—***Maintenance***—A definite maintenance schedule should be established for cleaning the windows and other light controlling media. The necessary frequency of cleaning depends upon whether the office is in a particularly clean or dirty location (Table III).

Figure 40. Use of clerestory windows provides more uniform daylighting within a room. (Photo Associates by Ulric Meisel.)

6. Daylighting of Industrial Buildings

6.1—***General***—**(a)** Illumination is a factor of primary importance in every industrial establishment. The beneficial effects of good illumination, both natural and artificial, have been established and recognized over many years. The advantages to industry are many: (176)

(1) Greater accuracy of workmanship resulting in an improved quality of product with less spoilage and reworking.
(2) Increased production and lowered costs.
(3) Better utilization of floor space.
(4) Greater ease of seeing, especially among older employees.

(5) More easily maintained cleanliness and neatness in the plant.
(6) Better supervision of workers.
(7) Improved morale among employees.
(8) Greater safety.

(b) Requirements for industrial daylighting follow those mentioned for good lighting practice: namely, an adequate level of well-distributed illumination with no excessive brightness ratios in the field of view. The chief difference in industrial daylighting is that a more flexible range of building design makes it easier to engineer these daylighting requirements.

(c) In order to establish a basis for good daylighting design and for choice between different daylighting systems, criteria as to illumination level, uniformity of illumination, etc., should be established.

Figure 42. The use of large windows in residences provides good lighting within rooms.

6.2—Recommended Illumination Level —The illumination resulting from a daylighting installation is chiefly dependent on the outdoor conditions at the particular time in question. As shown in Appendix C, the sky brightness on an overcast day varies with both time of day and season of the year. Consequently, in pre-determining daylight illumination for the design of a building, an equivalent sky brightness should be established. In most cases, a value representing minimum daylight conditions of 1000 footlamberts may be used as a basis for checking the design. The recommended value for illumination is dependent upon the type of work being done in the area in question. For any particular application, the designer should logically consider the lighting requirements which may be met by daylighting during the times of day in question and design the necessary fenestration to secure these values. (See Appendix B.) Minimum values of illumination for typical industrial tasks have been promulgated by the Illuminating Engineering Society and listed in the "American Standard Practice for Industrial Lighting." (A-11) A compilation of these values based on the ability to discern fine detail is given in Table VII. It should be noted that it may be economical to provide supplementary lighting or other auxiliary means for critical seeing tasks. For ideal conditions the illumination over the working plane should be as uniform as possible.

6.3—Orientation —The orientation and shape of industrial buildings depends upon so many conditions that no specific recommendations can be made. In some instances, however, it may be advantageous to face the rows of windows to the south in order to obtain maximum daylight during the dark months or to arrange the fenestration on all four sides. If this is done, it may be necessary to use some means of sunlight control.

6.4—Industrial Daylighting Using Side Wall Windows

6.4.1 —*Illumination Level*—The relative maintained illumination resulting from a large window (when the window length is equal to/or greater than five times the window height) is shown in Fig. 24. This curve is based on an equivalent sky brightness on an overcast day of 1000 footlamberts and was calculated by the methods described in Appendix E. It will be noted from this curve that under these conditions in order to obtain 30 footcandles, the window height should be at least equal to 50 per cent of the effective room width. When the windows are mounted on two opposite walls, the illumination at any point in the room is equal to the sum of the contributions from each window (Fig. 25). In order to obtain 30 footcandles in the center of the room, the combined heights of both

Figure 41. Large windows in residences provide light pleasant interiors.

Figure 43. Combination of clear glass window and glass block panels for lighting a living room.

windows should be at least 30 per cent of the building width.

6.4.2—*Distribution of Illumination*—The illumination from a window mounted in a side wall is maximum at the window sill (which is assumed to be on a level with the work plane) and decreases as the distance from the window increases. From Fig. 24 it will be seen that for a window height of 9 feet 5 inches, the direct illumination at a distance of 5 feet from the window with clear glass is 100 footcandles; while at a distance of 17 feet from the window the illumination is 30 footcandles.

6.4.3—*Brightness Ratios*—In order to reduce the brightness ratios at the work and the surroundings, the work should be arranged so that the person is not facing a source of high brightness. Suitable provision for control of sunlight on clear days should be made when fenestrations face other than north. (See Section 3.5.) The use of light-colored surfaces with a flat finish throughout the rooms and the use of window areas with minimum obstructions (such as mullions, airducts, and pipes) mounted in front of windows are an effective means for reducing brightness ratios.

6.5—*Glass Block in Side Walls*

Typical performance for unilateral and bilateral daylighting of industrial buildings fenestrated with light directional and light diffusing glass block is shown in Figs. 26 and 27. The illumination levels indicated are for an interior having a flat ceiling free of obstructions and for clean glass block. When these conditions are not met, somewhat lower illumination values should be anticipated.

6.6—*Industrial Daylighting Using Glass Areas Mounted Overhead*

6.6.1—*General*—An effective method of utilizing daylighting for single story buildings is to mount the fenestration overhead, as for example in skylights and monitors. The many possible arrangements using overhead glass areas enable the designer to obtain a high level of uniform illumination for a wide range of building conditions (Figs. 30, 31, and 32).

6.6.2—*Uniformity of Illumination*—

(a) The ratio of the maximum to the minimum illumination over any area depends upon the arrangement of the fenestration. It is advisable to have the illumination distribution as uniform as possible. In addition, uniform illumination distribution results in lower brightness ratios in the field of view, greater flexibility in task arrangements, and more effective utilization of floor space.

(b) The uniformity of illumination distribution improves as (1) the spacing between rows of windows decreases and (2) mounting height increases. Therefore, the ratio of mounting height to spacing gives an indication of the uniformity of illumination.

(c) When using the typical sawtooth arrangement with rows of windows all facing the same direction,

Figure 44. (Left) Example of combination of glass block panel and window for light and air with privacy. Figure 45. (Right) Example of glass block mounted to provide good lighting over the working surface.

Figure 46. Full utilization of daylight is obtained by mounting light curtains to the side of the windows.

reasonably uniform illumination is obtained when the mounting height is equal to or greater than the distance between window rows.

(d) Where each succeeding window faces in an opposite direction (monitors), uniform illumination can be obtained if the mounting height is equal to or greater than one half the distance between center lines of the monitors.

(e) For window mounting heights equal to one half the spacing between window rows, in the case of unilateral sawtooth construction, and one quarter the spacing between corresponding rows of windows in the case of bilateral monitor arrangements, the ratio between the maximum and minimum horizontal illumination on the working plane is of the order of 2:1. Mounting heights of one quarter the spacing between windows in the case of unilateral sawtooth construction and one eighth the spacing between corresponding rows of windows in the case of monitors, result in ratios of maximum to minimum illumination of 3:1 (Figs. 33-37). The distribution of illumination for the conditions shown in Figs. 33-37 were calculated by the methods described in Appendix E.

(f) High levels of uniform daylighting can be obtained by mounting the glass areas in monitors or sawtooths. Mounting the glass in a vertical or near-vertical plane minimizes light loss due to dirt accumulation. For effective daylighting design with these constructions, the following general considerations should be applied (Figs. 38 and 39). (118)

(1) Where only one monitor is planned, it is advisable to have the width of the monitor equal to one half the building width.

(2) Increasing the mounting height of the monitor or sawtooth above the working plane and the height of the glass results in a more uniform distribution of illumination.

TABLE VII—General Recommended Values of Illumination. (176)

	Current Recommended Practice Minimum Footcandles in Service (On Task or 30" above Floor)
MOST DIFFICULT SEEING TASKS	100 plus
Finest Precision Work	
Involving: Finest Detail	
Poor contrasts	
Long Periods of Time	
Such as: Extra fine Assembly;	
Precision Grading;	
Extra fine Finishing	
VERY DIFFICULT SEEING TASKS	100
Precision Work	
Involving: Fine Detail*	
Fair Contrasts	
Long Periods of Time	
Such as: Fine Assembly; High Speed Work;	
Fine Finishing	
DIFFICULT AND CRITICAL SEEING TASKS	50
Prolonged Work	
Involving: Fine Detail	
Moderate Contrasts	
Long Periods of Time	
Such as: Ordinary Bench Work and Assembly;	
Machine Shop Work; Finishing of	
Medium to Fine Parts; Office Work	
ORDINARY SEEING TASKS	30
Involving: Moderately Fine Detail	
Normal Contrasts	
Intermittent Periods of Time	
Such as: Automatic Machine Operation; Rough	
Grading; Garage Work Areas; Switch-	
boards; Continuous Processes;	
Conference and File Rooms	
CASUAL SEEING TASKS	10
Such as: Stairways; Reception Rooms; Washrooms	
and other Service Areas; Active Storage	
ROUGH SEEING TASKS	5
Such as: Hallways; Corridors; Passageways;	
Inactive Storage	

*Same task with 3 power magnifier, 1.5 footcandles

6.6.3—*Brightness Ratio*—In order to reduce brightness ratios between the task and the surroundings provisions may be necessary for control of direct sunlight. The use of flat or eggshell finishes having high reflectance throughout the room and the use of glass areas with minimum obstructions are effective means for further reducing brightness ratios.

6.7—*Reflecting Surfaces*—(a) In the daylighting design of industrial buildings, it is important to consider the reflectance of outside surfaces. (183) Light colored roofs, sidewalks, pavements, etc., should be used whenever possible.

(b) The use of non-glossy, light-colored interior surfaces and working surfaces such as machines, table tops, etc., increases the amount and distribution of daylight and lessens brightness ratios. This results in improved lighting conditions, improved appearance, and tends to encourage better maintenance.

6.8—*Maintenance*—(a) Windows, like other lighting units, accumulate dust and grease on their surfaces and

thus transmit less light. The amount of this reduction depends upon the location, the angle at which the glass is mounted, and the frequency of cleaning. Typical depreciation factors for factory conditions are shown in Table III.

(b) Experiments have shown that the accumulation of dirt on a window over a given length of time is about 75 per cent on the inside and 25 per cent on the outside. (116) In order to reduce the dirt accumulation when rough surface glass is used the smooth side should be facing the area which is likely to contain the most dirt.

(c) The frequency of cleaning should depend upon the rate of light loss through the windows, and should be in general at least twice a year. (22) However, if cleaning is done only once a year, this cleaning should be done in the fall. (116)

(d) In the building design, consideration should be given to the maintenance of the windows and, if necessary, means provided for facilitating this work; *e.g.*, catwalks for monitor and sawtooth buildings, access to the roof where the windows can be reached and washed from the outside, etc. This is particularly important where large window areas are involved.

6.9—*Multistory Building Arrangements*—(a) In designing for daylighting in multistory buildings, consideration should be given to the placement of the building on the lot. Whenever possible, the building should be arranged so that other buildings in the area or other parts of the same building do not obstruct the daylight. (185)

(b) Where several buildings form an enclosure, consideration should be given to providing the enclosing walls with a diffusing surface that will reflect the maximum amount of light.

(c) In order to obtain the same amount of illumination on the lower floors, as on the upper floors, for "H" and "E" shaped buildings consideration should be given to the use of higher windows in the lower stories, in order to compensate for the smaller amount of light available.

Figure 47. Large glass areas in homes blend the indoors with the outside.

7. Daylighting in Homes

7.1—*General*—The trend in houses of today is to larger glass areas. Carefully planned fenestrations in homes result in light, pleasant interiors and sunlight in the desired rooms at the preferred times. In general, in the daylighting of homes, lighting from both the sun and the sky is desirable.

7.2—*Orientation*—The orientation of a house depends upon many conditions as well as the preference for sunlight in certain rooms at specific times. Consequently, definite criteria for orientation are not established.

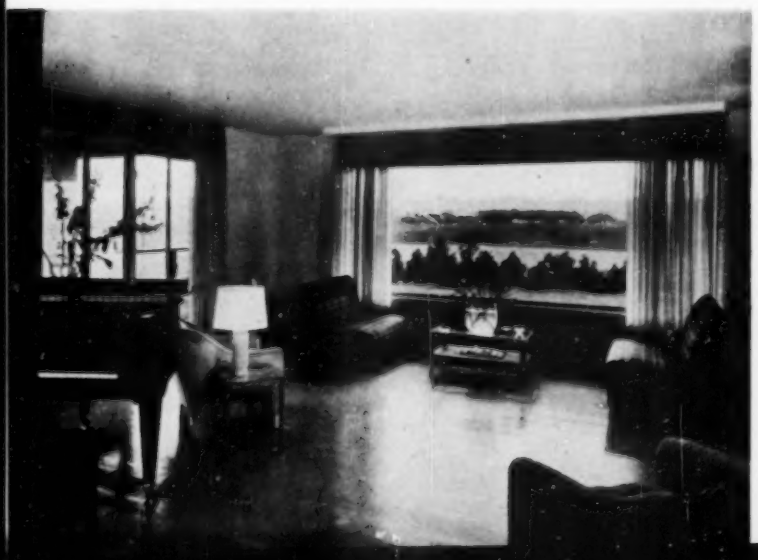
7.3—*Fenestration*—(a) The fenestration affects the amount and distribution of light in a room. In the daylighting of homes, it is important that the daylight be evenly distributed, with no dark corners in the room. In order to obtain a good overall spread of light, wherever possible large glass areas should be used in more than one wall.

(b) For a given glass area along any one wall greater uniformity of illumination will result if two or more windows are used. From a daylighting point of view, it is desirable to have one large glass area mounted across the entire wall.

(c) Consideration is sometimes given to the use of a clerestory to provide light in the back of a room (Fig. 40).

(d) Examples of residence fenestra-

Figure 48. Picture windows create bright pleasant interiors with plenty of daylight.



tions are shown in Figs. 40-48 inclusive.

(c) To obtain reasonable levels of daylighting, the glass area should be as large as possible. The ratio of glass to floor area, wherever possible, should be not less than 20 per cent.

7.4—Interior Decoration — **(a)** For maximum daylighting walls, ceilings, and floors should be given a flat or eggshell finish in light colors.

(b) Many good daylighting installations have been made ineffective by the use of heavy drapes and shades over the windows. Experiments (190) indicate that arrangements of drapes similar to those shown in Figure 49 result in an illumination in the rear of the room equal to twice that obtained when using a curtain arrangement like that shown in Fig. 50. Whenever possible, therefore, drapes and curtains should be mounted at the side of the windows (*Fig.* 46).

Appendix A

Definitions of Terms

For the purpose of this report the following definitions are given to clarify the text:*

*The following sources were used in compiling the above definitions: "Illuminating Engineering Nomenclature and Photometric Standards," ASA Z7.1-1942; *American Ephemeris and Nautical Almanac*, Gov't Printing Office, 1937; *American Standard Definitions of Electrical Terms*, ASA C42-1941; *Webster's New International Dictionary*, G. and C. Merriam Company, Springfield, 1947; *I.E.S. Lighting Handbook*, Illuminating Engineering Society, 1947.

Altitude — The angular distance of a heavenly body measured on that great circle which passes perpendicular to the plane of the horizon, through the body and through the zenith. It is measured positively from the horizon to the zenith, from 0° to 90°. See Fig. 3.

Azimuth — The azimuth of a line or celestial body is the angle between the vertical plane containing the line or celestial body and the plane of the meridian. See Fig. 3.

Brightness — Brightness is the luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

Brightness Contrast and Brightness Ratio — Variations in brightness are indicated as brightness contrast or brightness ratio. As used in this report, brightness contrast expresses the variations or contrast in brightness of the details of a visual task, such as black or grey print on white paper. Such details or objects are usually adjacent in the visual field. Brightness ratio is here used to express the ratio between the brightnesses in the field of vision which have an influence on the adaptation of the eyes, such as between paper and desk, windows and walls, between adjacent wall areas, light sources or luminaires and ceilings, etc.

Clear Sky — Clear sky is that in which less than 30 per cent of the total sky is covered by clouds.

Cloudy and Partly Cloudy Sky — Cloudy sky is that in which more than 70 per cent of the sky is covered by clouds. Partly clouded sky conditions is when more than 30 per cent and less than 70 per cent is covered by clouds.

Clerestory — That part of a building which rises clear of the roofs of the other parts, and whose walls contain windows for lighting the interior.

Daylight — The light from the sun and sky during the time from sunrise to sunset.

Diffusing Surfaces and Media — Diffusing surfaces and media are those which break up and distribute the incident light.

Fenestration — Any opening or arrangement of openings (normally filled with media for control) for the admission of daylight.

Footcandle — The footcandle is the unit of illumination when the foot is taken as the unit of length. It is the illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen, or the illumination produced at a surface all points of which are at a distance of one foot from a uniform point source of one candle.

Footlambert — The footlambert is a unit of brightness equal to the uniform brightness of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot; or to the average brightness of any surface emitting or reflecting light at that rate.

Illumination — The density of luminous flux (light) incident on a surface.

Latitude — The geographical latitude of a point is the angle, measured in the plane of the local meridian, between

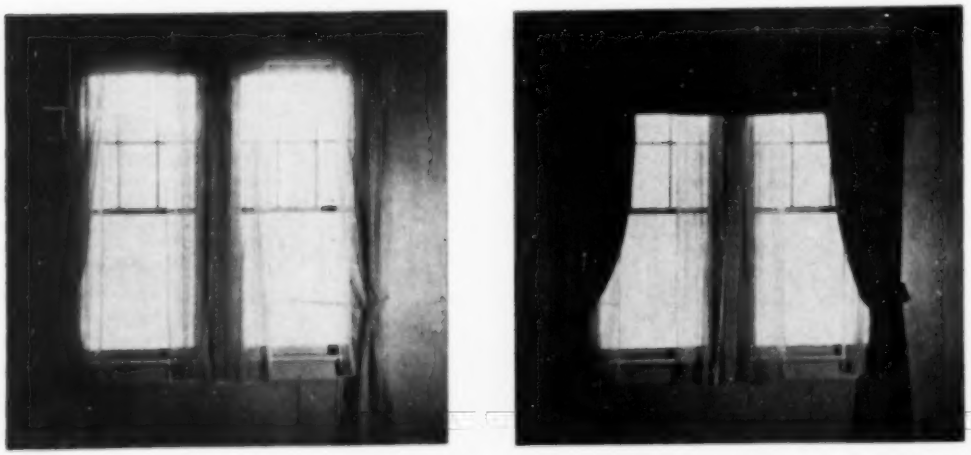


Figure 49. (Left) Light curtains have little effect on the amount and distribution of daylighting in this room. Figure 50. (Right) Heavy opaque drapes greatly reduce the illumination from this window.

the equator and a line perpendicular to the surface of the earth through the point in question.

Light — For the purpose of illuminating engineering, light is radiant energy evaluated according to its capacity to produce visual sensation.

Longitude — The longitude of a point on the surface of the earth is the angular distance measured along the earth's equator from the meridian through Greenwich, England, to the local meridian through the point. Longitude is measured either east or west from Greenwich through 180° or 12 hours.

Lumen — The lumen is the unit of luminous flux. It is equal to the flux through a unit solid angle (steradian) from a uniform point source of one candle; or to the flux on a unit surface all points of which are at unit distance from a uniform point source of one candle.

Maintenance Factor — The ratio of the light transmission after a designated period of time to the initial light transmission. This is a measure of light admitted with an accumulation of dirt, and dust etc. to that admitted when clean.

Monitor — The portion of a building that is raised above the general roof level, usually with two sides fenestrated for the admission of daylight to the interior.

Mounting Height — The height of the window sill above the working plane. This applies to sidewall windows, monitors, sawtooth construction, etc.

Orientation — Positioning of a building with respect to compass positions.

Overcast Sky — An overcast sky is one in which the entire sky is covered by clouds and the sun is not visible. The typical brightness of an overcast sky varies from a minimum at the horizon to a maximum directly overhead and is approximately independent of azimuth.

Projection — An overhang or shade extending from a building; usually of a fixed nature; used to exclude direct sunlight.

Reflectance — The reflectance of a body is the ratio of the light reflected by the body to the incident light.

Reveal — The side of an opening for a window.

Solar Illumination — The illumination from the sun, with the light from the sky excluded.

Solar Time (Apparent or True) — Solar time is measured by the diurnal motion of the sun. Noon is taken as the instant in which the center of the sun passes the observer's meridian. This is the time measured by sun dials.

(Mean Solar Time) — Mean solar time is measured by the diurnal motion of a fictitious body called the mean sun. It differs from the apparent solar time by eliminating irregularities produced by the eccentricities of the earth's orbit and by the obliquity of the ecliptic. Corrections to be made to apparent solar time to determine mean solar time for different times of the year are as follows:

Jan.	21 + 11 min.	July	21 + 6 min.
Feb.	21 + 13 min.	Aug.	21 + 3 min.
Mar.	21 + 8 min.	Sept.	21 — 7 min.
Apr.	21 — 2 min.	Oct.	21 — 15 min.
May	21 — 3 min.	Nov.	21 — 14 min.
June	21 + 1 min.	Dec.	21 — 2 min.

(Standard Time) — Standard time, used almost universally, is advanced on the idea of 24 standard meridians 15° apart. In the United States and Canada, the standard meridians and time belts are as follows:

Area	*Standard Meridian W. Long*	*Time Difference from Greenwich*
Atlantic Standard Time	60°	4 hours
Eastern Standard Time	75°	5 "
Central Standard Time	90°	6 "
Mountain Standard Time	105°	7 "
Pacific Standard Time	115°	8 "

Apparent solar time can be converted to standard time by first correcting to local mean solar time and then correcting the longitude in question to agree with the prime meridian of the standard time zone of the site being investigated. If the location for which the computation is being made is west of the prime meridian of its standard time zone, a correction of four minutes of time added to the mean solar time must be made for each degree westward of the standard time meridian, and four minutes subtracted for each degree eastward.

Transmission Factor — The transmission factor of a body is the ratio of the light transmitted by the body to the incident light.

The Regular or Direct Transmission is that in which the transmitted light is not diffused. In such transmission, the direction of a transmitted beam of light has a definite geometrical relation to the corresponding incident beam.

The Diffuse Transmission Factor of a body is the ratio of the diffusely transmitted light to the incident light.

Window Height — The distance between the window sill and the head of the window.

Window — An opening in the wall of a building for admission of light and air, usually closed by light transmitting media.

Appendix B
Light and Vision

B-1—*What is good lighting?* —Lighting must be based on the light source as well as the characteristics of the surround. It is good when it is suitable in quantity and quality for the purpose of creating general environmental brightness agreeable and beneficial to the user, and for permitting a high degree of efficiency in seeing whatever is of special interest or importance.

B-2—*Criteria for Lighting* —Various experimental methods have been used to determine the characteristics of certain attributes of seeing under different methods of lighting. Three of the most widely used methods involve the measurements under controlled conditions of the acuity of perception, the speed of vision, and the degree to which a just noticeable change in brightness can be detected for different levels of illumination. The results of these tests all indicate that for all other things being equal, the higher the brightness of the task, the greater is the visual performance. Other testing procedures include the use of visibility meters, psycho-physiological tests, (such as nervous muscular tension as a function of brightness levels) etc. (1, 13, 14, 15, 26, 28)

B-3—*Glare* — **(a)** The ability to see minute detail or small degrees of contrast is lessened by high brightness ratios in the field of view (glare). The relative visual acuity as a function of different brightness ratios in the field of view as determined by tests is shown in Table B-I (11, 21)

(b) This table illustrates the importance of eliminating high brightness ratios involving large areas from the field of view.

(c) Glare can be either direct, due to a bright light source or reflected from a shiny surface in the field of view.

(d) For the purpose of glare analysis, the field of view can be thought of as consisting of three visual fields: the *central field*, which is considered to be the visual task; the *surrounding field*, which extends approximately 30 degrees on each side of the optical axis or line of sight; and the *peripheral field*, which lies outside the surrounding field and includes an area approximately 120 degrees vertically and 160 degrees horizontally. (12)

B-4—*Lighting Recommendations* — **(a)** The recommended level of illumination for any visual task is a compromise between economics and the desired visual performance. The recommended level for any task is therefore based on the current practice and subject to change with the development of more effective means of utilizing light.

(b) Since the level of illumination for equal seeing conditions depends upon the contrasts and the difficulty of the visual task, a scale of recommended levels for different conditions has been suggested. (10, 11)

(c) As brightness ratios in the field of view affect the ability to see, seeing comfort for given lighting, and brightness levels, the limits of brightness ratios must be specified as well as lighting levels. The Committee on Standards of Quality and Quantity for Interior Illumination of the Illuminating Engineering Society has recommended a ratio between the task brightness and that of the immediate surround of 1:1 for optimum seeing and 3:1 for good seeing. For less critical seeing tasks this value may be increased.

TABLE B-I.—Ratio of Brightness of Surround to Brightness of Task.

Ratio of brightness of immediate surround to brightness of task	Relative Visual Acuity
0.1	.93
1	1.0
3	.80
10	.65
50	.30
100	.15

Appendix C
Sky Brightness

C-1—*General* — **(a)** The sky brightness is the result of the scattering of sunlight by the atmosphere. The sky brightness depends upon the amount and distribution of the clouds and on the position of the sun.

(b) The degree of cloudiness as determined by the U. S. Weather Bureau is visually appraised by the proportion of the cloud area to the total sky area. The average number of clear and cloudy days based on a 38 year study (39) for different parts of the United States is given in Figs. C-1 and C-2.

C-2—*Sky Brightness (Clear Day)* — The amount and distribution of the sky brightness varies with the position of the sun. In general, the sky brightness is greater near the sun and near the horizon and decreases as distances from these points increase. Brightness distributions for clear sky at Washington, D. C. with the sun at altitudes of 0, 20, 40, and 60 degrees are given in Figures C-3, C-4, C-5, and C-6. (48,52) These figures are stereographic projections of the half of the sky on either side of the sun's vertical. The brightness of each region of the sky is expressed in millilamberts and in the ratio to the zenith brightness.

C-3—*Sky Brightness (Overcast Day)* — **(a)** On a completely overcast day the sky brightness distribution is nearly independent of the solar altitude and azimuth and can be approximated by a simple relation. The brightness distribution for a typical overcast sky condition is shown in Fig. C-7.

(b) The sky brightness on an overcast day as measured by the illumination on a horizontal plane is shown in Fig. C-8. These values are minimum and average values for Atlantic Coast states and Central Plains states.

C-4—*Equivalent Sky Brightness* — **(a)** In the case of a very large diffuse source covering a hemisphere such as the sky having a uniform brightness, the illumination on a horizontal plane measured in footcandles is equal to the brightness of the source measured in footlamberts. The illumination on a vertical surface for the same conditions, and assuming no ground reflectance, is equal to one half the sky brightness.

(b) The horizontal and vertical illumination on clear and cloudy days as a function of solar altitude and azimuth from the sun is given in Figs. C-9 and C-10.

(c) As the brightness distribution throughout the sky on both clear and cloudy days is non-uniform, various simplifying methods have been used to evaluate the sky brightness. It is customary to express the equivalent sky brightness

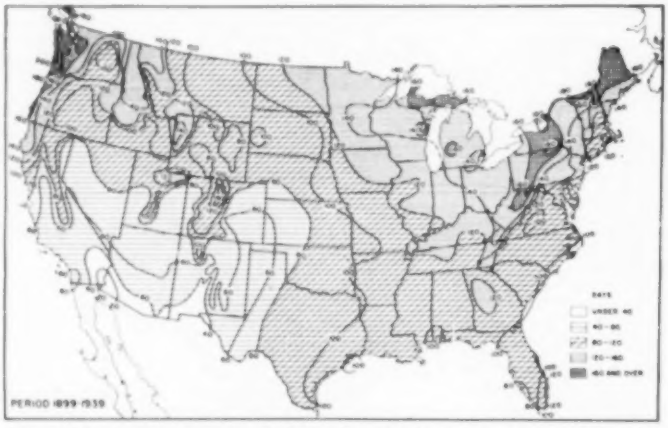
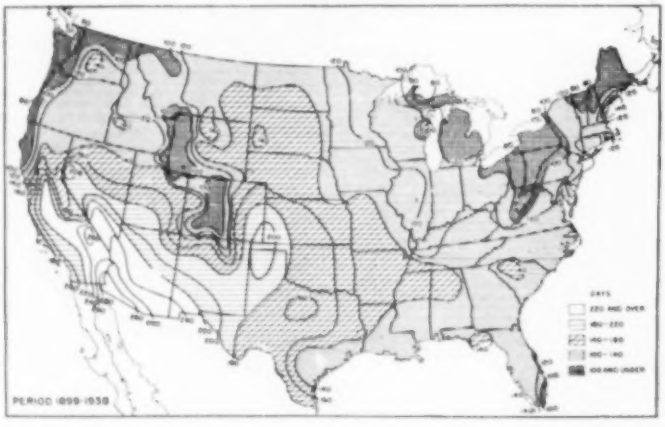


Figure C-1. Average number of cloudy days (at least 70% of sky covered by clouds). (Ref. 39)

Figure C-2. Average number of clear days (less than 30% of sky covered by clouds). (Ref. 39)



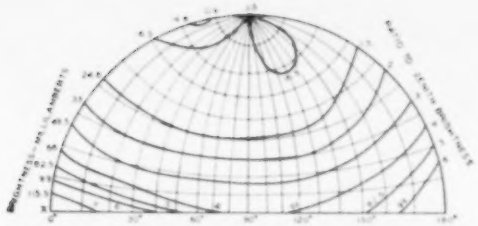


Figure C-3. Brightness distribution, clear sky. Solar altitude 0°; sun's position indicated by X. Brightnesses in millilamberts (1 mL = 0.929 ft-L) and as ratio to zenith brightness. Measurements taken at Washington, D. C. (Ref. 48-52)

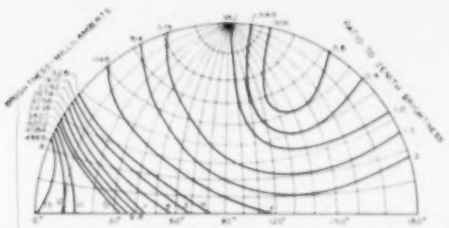


Figure C-4. Brightness distribution, clear sky. Solar altitude 20°; sun's position indicated by X. Brightnesses in millilamberts (1 mL = 0.929 ft-L) and as ratio to zenith brightness. Measurements taken at Washington, D. C. (Ref. 48-52)

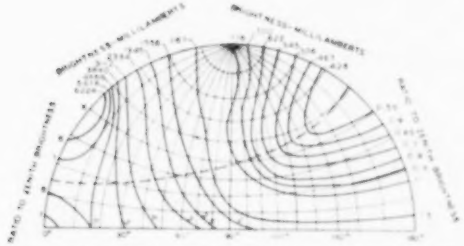


Figure C-5. Brightness distribution, clear sky. Solar altitude 40°; sun's position indicated by X. Brightnesses in millilamberts (1 mL = 0.929 ft-L) and as ratio to zenith brightness. Measurements taken at Washington, D. C. (Ref. 48-52)

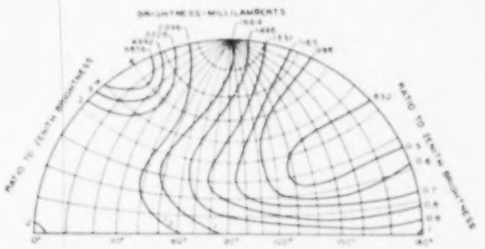


Figure C-6. Brightness distribution, clear sky. Solar altitude 60°; sun's position indicated by X. Brightnesses in millilamberts (1 mL = 0.929 ft-L) and as ratio to zenith brightness. Measurements taken at Washington, D. C. (Ref. 48-52)

as a single value which is equal to one of the following values:

(1) A uniform brightness equal to the illumination on a horizontal plane.

(2) A uniform brightness equal to twice the illumination on a vertical plane.

(3) A uniform brightness equal to the brightness as viewed from a point in the room through the center of the window opening.

(4) A non uniform brightness related to the illumination on a horizontal plane from the unobstructed sky. The brightness distribution is usually taken as the distribution of an overcast sky, which can be expressed by the formula:

$$B_\theta = 3/7\, E_h\, (1 + 2 \sin \theta)$$

where

B_θ = sky brightness at angle θ above the horizon

E_h = illumination on horizontal plane from unobstructed sky.

Appendix D
Solar Radiation

D-1—*General* — **(a)** The sun follows a fixed path and for any given time or location it is possible to determine the sun's position from mathematical formulae (31, 80). The solar altitude and azimuth for different latitudes and times is shown in Table IV.

(b) The presence of sunlight in rooms is psychologically pleasing and desirable. In one instance sunlight in classrooms has been recommended because of the pleasing characteristics. (25, 169) The method of predetermining the amount and penetration of sunlight is described below.

D-2—*Solar Penetration* — The distance to which sunlight will penetrate into a room or the amount of shading from a fixed horizontal or vertical building projection can be obtained from geometrical formulae involving the solar altitude and

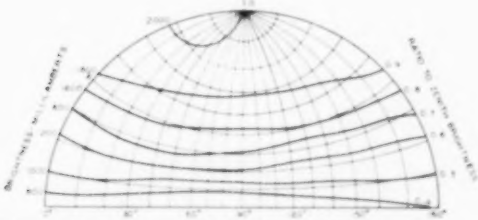


Figure C-7. Brightness distribution, overcast sky. Solar altitude 40°; sun's position indicated by X. Brightnesses millilamberts (1 mL = 0.929 ft-L) and as ratio to zenith zenith brightness. Measurements taken at Washington, D. C. (Ref. 48-52)

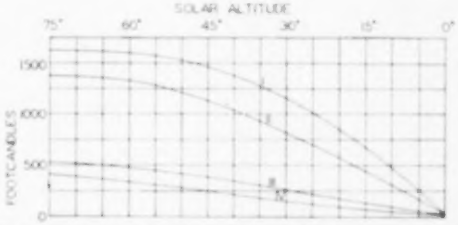


Figure C-8. Illumination with a cloudy sky. Curve I average for Plains States. Curve II average for Atlantic Coast States. Curve III minimum for Plains States. Curve IV minimum for Atlantic Coast States.

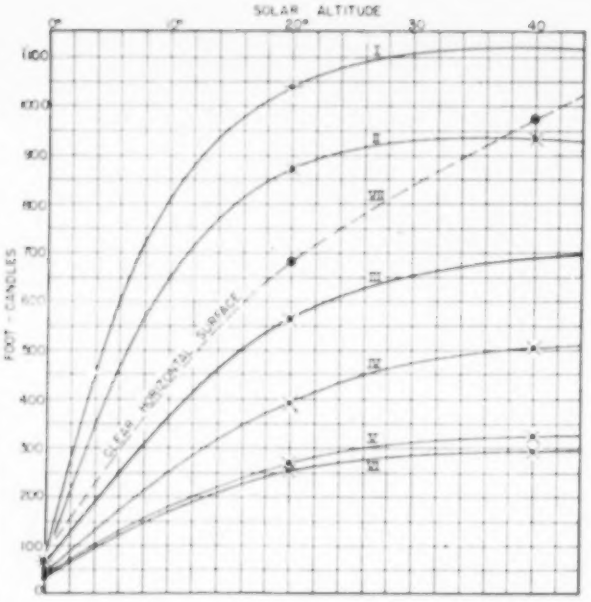


Figure C-9. (Top) Curves of winter skylight illumination on different surfaces:

Curve I.	**Clear sky. Vertical surface facing 0° in azimuth from sun.**
Curve II.	**Clear sky. Vertical surface facing 45° in azimuth from sun.**
Curve III.	**Clear sky. Vertical surface facing 70° in azimuth from sun.**
Curve IV.	**Clear sky. Vertical surface facing 90° in azimuth from sun.**
Curve V.	**Clear sky. Vertical surface facing 135° in azimuth from sun.**
Curve VI.	**Clear sky. Vertical surface facing 180° in azimuth from sun.**
Curve VII.	**Clear sky. Horizontal surface.**

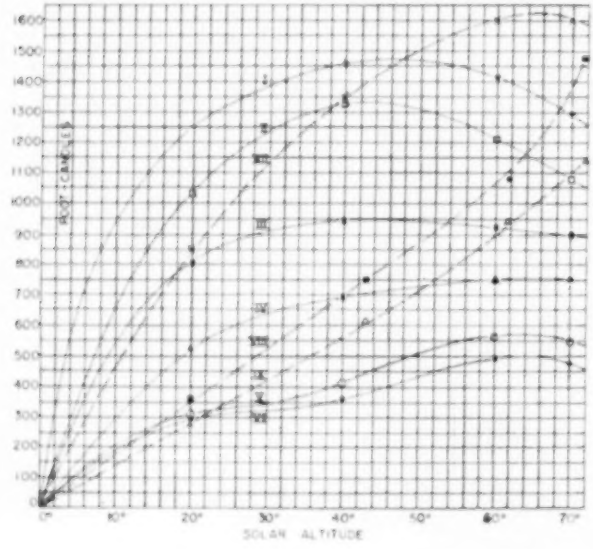


Figure C-10. (Bottom) Curves of summer skylight illumination on different surfaces:

Curve I.	**Clear sky. Vertical surface facing 0° in azimuth from sun.**
Curve II.	**Clear sky. Vertical surface facing 45° in azimuth from sun.**
Curve III.	**Clear sky. Vertical surface facing 70° in azimuth from sun.**
Curve IV.	**Clear sky. Vertical surface facing 90° in azimuth from sun.**
Curve V.	**Clear sky. Vertical surface facing 135° in azimuth from sun.**
Curve VI.	**Clear sky. Vertical surface facing 180° in azimuth from sun.**
Curve VII.	**Clear sky. Horizontal surface.**
Curve VIII.	**Cloudy sky. Horizontal surface. (Note: Double the intensity scale)**
Curve IX.	**Cloudy sky. Vertical surface.**

azimuth and the building orientation (Fig. D-1). The amount of the window shaded from a long horizontal overhang mounted above the window can be calculated from the formula:

$$h = D_o \sec (\Psi_z - \Psi_x) \tan \theta$$

where

h = height of shadow below overhang

D_o = depth of overhang from the window surface

Ψ_z = solar azimuth

Ψ_x = angle between outward drawn normal to the window and true south

θ = solar altitude above the horizon

The amount of shading from a vertical projection mounted at the side of a window can be obtained from the formula:

$$W = D_v \tan (\Psi_z - \Psi_x)$$

where W = the width of the shadow from the side projection

D_v = depth of vertical projection

In planning fixed horizontal and vertical projections for sunlight control, it is advisable to calculate the window shading for several different months and times by the use of the above formulas. In that way the overhang dimensions for any desired shading can be obtained.

D-3—*Solar Radiation*—(a) The radiant energy from the sun at normal incidence is subject to variations due to the following factors: (57) variations in the distance from the earth to the sun, differences in atmospheric scattering by air molecules, water vapor and dust, differences in atmospheric absorption.

(b) A study has been made assessing these variables based upon all the available test information and a series of solar irradiation curves based upon standard conditions has been proposed. These curves, shown in Fig. D-2, give the solar radiation at sea level expressed in watts per square meter per micron, for all wavelengths and for different air masses. The air mass is approximately equal to the cosecant of the altitude.

D-4—*Solar Illumination*—The direct solar illumination can be obtained by evaluating the solar radiation curve with respect to the standard luminosity function. (57) The solar illumination on a horizontal plane and a plane normal to the sun's rays for different times and latitudes is given in Table V.

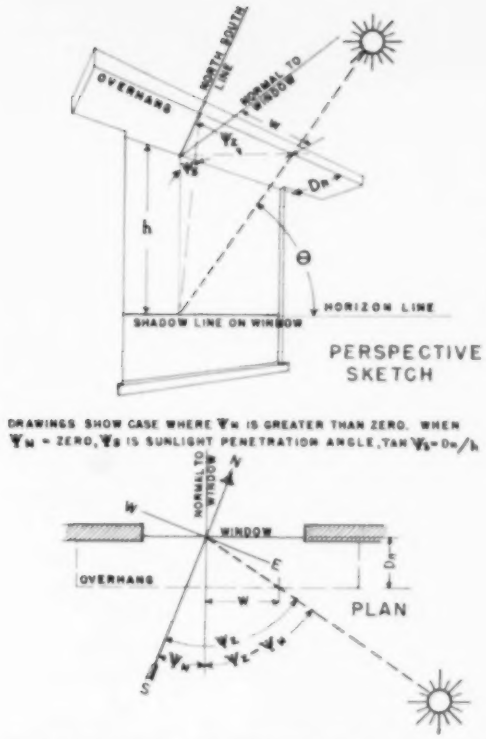


Figure D-1. Sunlight shading from horizontal overhang. (Drawing by K. C. Welch)

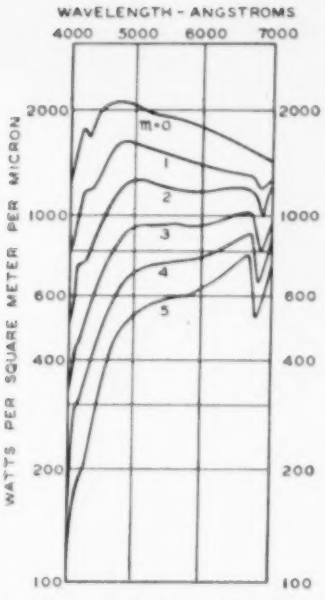


Figure D-2. Solar Radiation Curves. Visible range 4000-7000 angstroms. (Ref. 57)

Appendix E
Daylighting Prediction Methods

E-1—*General*—(a) Methods for the calculation of direct light from diffuse, rectangular surface sources have been developed by many investigators. (65-131) Most of the different methods are based on the same principles and the results obtained are in general agreement. The differences can be accounted for by the fact that in some instances, in an effort to simplify the calculations, assumptions have been made which for all practical purposes do not limit the range over which sufficiently accurate calculations can be made.

(b) Mathematical equations have been established which enable the calculation of illumination at any point and at any plane from a surface source of any known distribution. (109, 98) The mathematics is rather cumbersome, and in order to simplify these calculations a graphical solution is normally used.

E-2—*Light Distribution from Rectangular Surface Sources*

E-2.1—*General*—**(a)** The calculation of light from a rectangular source is usually done at a point perpendicular to the corner of the source. The variables involved are the distance from the source L, the height of the source H, the width W, and the brightness B. (See Fig. E-1.) The planes in which the illumination is usually calculated are a horizontal plane E_h and a vertical plane E_v.

(b) The illumination can be determined for any point on a plane, in relation to the source, by the principle of superposition. For instance, if it is desired to calculate the illumination at point P, from source D, Fig. E-2, the illumination is first calculated from source $ABCD$ and then from sources A, AC, and AB. The illumination from source D is then equal to the illumination from source $ABCD$ minus the sum of the illumination from sources AB and AC, plus the illumination from source A.

E-2.2—*Uniform Source*—**(a)** The illumination from a rectangular source of uniform brightness, assuming no glass in the rectangular opening and no contributions from walls and ceilings, can be obtained from the graphs shown in Figs. E-3 and E-4. (109) For example, to obtain the illumination at distance 10 feet from a rectangular uniform source 20 feet wide and 10 feet high, which is perpendicular to the illuminated plane, obtain the values of window width to height (20/10) and the distance from the window to window height (10/10). From Fig. E-4 follow the curve $W/H = 2$ until it strikes the ordinate $L/H = 1$; the ratio of illumination to source brightness for this condition is .07. Assuming a uniform source brightness of 1000 footlamberts then the illumination is 70 footcandles.

(b) For daylighting calculations involving windows with glass, the illumina-

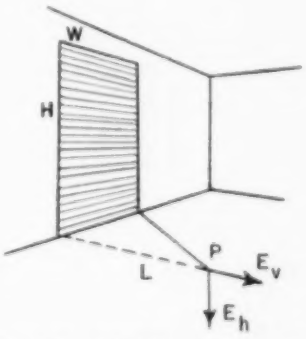


Figure E-1. Calculation of illumination from surface source.

TABLE E-I.—Footcandles for Vertical Windows with Sill at Working Plane

Feet Back from Window	16" High Panes and Height Dimensions										
	4 5'-5"	5 6'-9"	6 8'-1"	7 9'-5"	8 10'-9"	9 12'-1"	10 13'-5"	11 14'-9"	12 16'-1"	13 17'-5"	14 18'-9"	15 20'-1"
5	69.7	80.5	90.5	99.1	106.7	113.4	118.8	123.6	127.7	131.5	135.0	138.0
10	36.5	43.9	51.9	60.1	68.2	76.3	84.5	91.8	97.4	102.8	107.8	112.1
15	20.9	25.9	31.5	37.3	44.8	51.1	56.9	62.7	68.3	74.3	80.0	85.3
20	13.4	16.6	20.3	24.9	30.0	36.9	42.1	47.3	52.1	57.3	62.3	67.5
25	9.3	11.4	13.9	17.0	21.5	26.2	30.5	35.1	39.7	43.9	48.6	53.5
30	6.8	8.4	10.3	12.8	16.2	19.7	23.1	26.8	30.5	34.5	38.8	43.2
35	5.0	6.4	8.0	9.9	12.4	15.0	17.6	20.5	23.9	27.3	30.9	34.7
40	3.9	4.9	6.2	7.6	9.6	11.9	14.2	16.4	19.1	21.6	24.9	27.6
45	3.0	3.9	5.0	6.1	7.5	9.2	11.1	13.0	15.3	17.6	20.0	22.4
50	2.5	3.1	3.9	4.8	6.1	7.5	9.1	10.6	12.3	14.1	16.2	18.4
55	2.0	2.6	3.3	4.0	5.0	6.1	7.4	8.7	10.2	11.6	13.3	14.9
60	1.7	2.2	2.7	3.4	4.2	5.1	6.2	7.2	8.4	9.6	11.0	12.4
65	1.4	1.8	2.3	2.8	3.5	4.2	5.2	6.0	7.0	8.1	9.2	10.4
70	1.2	1.5	1.9	2.4	3.0	3.7	4.5	5.3	6.1	7.0	7.9	9.0
75	1.0	1.3	1.7	2.1	2.6	3.2	3.8	4.5	5.3	6.0	6.9	7.7
80	0.9	1.1	1.5	1.8	2.3	2.8	3.4	4.0	4.6	5.3	6.0	6.8
85	0.8	1.0	1.3	1.6	2.0	2.5	3.0	3.5	4.0	4.7	5.3	6.0
90	0.7	0.9	1.1	1.4	1.8	2.2	2.6	3.1	3.5	4.2	4.8	5.4
95	0.6	0.8	1.0	1.3	1.6	1.9	2.3	2.7	3.1	3.6	4.2	4.8
100	0.5	0.7	0.9	1.2	1.4	1.8	2.0	2.4	2.8	3.3	3.8	4.3

TABLE E-II.—Footcandles for Vertical Windows Above the Working Plane.

Feet Back from Window	15 Feet Above Window Height				25 Feet Above Window Height				35 Feet Above Window Height			
	5'-5"	6'-9"	8'-1"	9'-5"	5'-5"	6'-9"	8'-1"	9'-5"	5'-5"	6'-9"	8'-1"	9'-5"
5	16.8	19.5	21.4	23.0	4.6	5.4	6.2	7.0	2.9	3.9	4.2	4.7
10	20.5	24.9	28.1	30.8	8.1	10.3	11.5	13.1	5.3	6.6	7.7	8.9
15	21.9	26.8	31.6	35.1	11.8	14.6	16.3	18.6	8.1	10.0	11.6	13.4
20	22.0	27.3	31.9	35.7	13.7	17.2	19.9	22.2	10.3	12.4	14.6	17.0
25	19.7	24.3	27.6	31.6	14.3	18.1	21.1	24.0	11.0	13.5	16.1	18.4
30	16.2	19.5	23.0	26.8	13.9	17.7	20.8	23.9	11.2	13.9	16.4	18.8
35	13.4	16.6	19.5	23.1	13.0	16.9	19.3	22.6	11.1	13.9	16.4	18.8
40	11.2	14.2	16.6	19.7	11.5	14.1	16.9	19.6	10.8	13.5	16.0	18.2
45	9.6	12.2	14.3	17.0	10.1	12.6	15.0	17.4	10.6	12.3	14.6	16.8
50	8.1	10.3	12.3	14.3	8.9	11.2	13.4	15.6	8.9	11.1	13.3	15.3
55	6.8	8.7	10.5	12.2	8.0	10.2	12.0	14.1	8.0	10.0	12.0	13.9
60	5.7	7.2	8.7	10.1	7.2	9.1	10.8	12.6	7.3	9.2	11.0	12.7
65	4.7	6.0	7.2	8.5	6.4	8.1	9.6	11.1	6.5	8.4	10.0	11.6
70	3.9	5.0	6.1	7.3	5.6	7.2	8.4	9.8	5.9	7.6	9.2	10.7
75	3.3	4.3	5.3	6.2	4.9	6.3	7.5	8.7	5.4	6.9	8.4	9.8
80	2.9	3.7	4.6	5.5	4.3	5.4	6.5	7.6	5.0	6.2	7.6	8.9
85	2.6	3.3	4.1	4.9	3.9	4.9	5.8	6.8	4.5	5.6	6.8	8.0
90	2.4	3.0	3.6	4.4	3.4	4.4	5.2	6.1	4.1	5.0	6.1	7.3
95	2.1	2.7	3.3	3.9	3.1	3.9	4.8	5.6	3.6	4.5	5.5	6.6
100	2.0	2.5	3.0	3.6	2.8	3.5	4.4	5.1	3.3	4.1	5.0	6.0

TABLE E-III.—Footcandles from 30 Degree Sloping Windows Above Working Plane.

Feet From Plane of Window	*15 Feet Above Working Plane Window Height				*25 Feet Above Working Plane Window Height				*35 Feet Above Working Plane Window Height			
	3'-0"	6'-0"	9'-0"	12'-0"	3'-0"	6'-0"	9'-0"	12'-0"	3'-0"	6'-0"	9'-0"	12'-0"
5	28.6	47.2	56.5	51.6	6.1	10.8	11.6	15.7	2.6	5.2	6.7	8.3
10	14.2	25.9	64.3	78.8	12.0	21.4	26.5	31.1	5.3	9.8	13.2	16.7
15	28.9	54.4	69.3	85.0	15.2	29.9	40.8	50.0	8.2	14.8	20.4	25.1
20	21.9	44.9	65.8	83.3	16.9	33.7	48.5	60.5	11.0	20.4	27.5	33.7
25	17.1	36.1	55.9	75.0	17.6	33.7	48.5	62.2	13.1	24.2	33.7	41.9
30	12.8	27.8	45.1	62.5	17.1	33.1	47.4	61.0	13.4	25.9	37.7	48.0
35	9.5	20.8	34.2	49.7	15.3	30.6	45.5	58.2	13.2	25.9	38.9	51.3
40	6.7	15.5	27.3	40.8	13.4	27.6	41.1	53.8	12.8	25.5	38.7	51.5
45	4.9	12.5	22.7	33.8	11.5	23.7	36.0	48.7	12.2	24.5	37.0	49.5
50	4.5	10.2	18.9	28.4	10.0	20.7	32.0	43.6	11.2	22.5	34.2	46.0
55	3.7	8.6	15.1	24.2	8.3	17.9	27.8	37.5	10.0	20.1	31.1	42.2
60	3.2	7.2	13.1	20.4	7.0	15.2	23.9	32.5	8.8	18.1	27.8	38.3
65	2.6	6.0	10.5	16.8	6.0	13.0	20.8	28.3	7.7	16.0	24.8	34.1
70	2.2	4.9	8.4	13.4	5.0	11.0	17.5	24.3	6.8	14.1	21.6	29.6
75	1.8	3.9	6.9	10.8	4.2	9.1	14.6	20.6	6.0	12.3	18.9	26.0
80	1.5	3.3	5.8	8.9	3.5	7.4	11.9	17.1	5.1	10.6	16.5	22.7
85	1.2	2.8	4.8	7.4	2.9	5.9	9.6	14.0	4.1	9.1	14.2	19.8
90	1.0	2.4	4.0	6.2	2.3	4.7	7.7	11.3	3.6	7.8	12.4	17.4
95	0.9	2.0	3.3	5.1	1.9	4.0	6.5	9.3	3.0	6.8	10.9	15.3
100	0.8	1.7	2.9	4.4	1.7	3.4	5.6	8.1	2.6	6.0	9.6	13.5

*Sill and height measured to plane of window.
Basis for Tables E-I, E-II, and E-III:
Clear glass with transmission 74 per cent of 90 per cent
Window obstruction 20 per cent
Sky brightness 1000 footlamberts

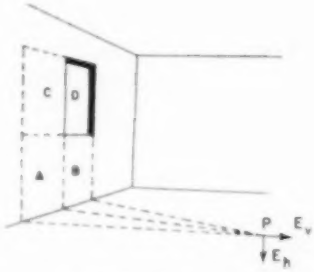


Figure E-2. Example of illumination calculation from source "D."

tion from a source of uniform brightness at a point in a room should be multiplied by the transmission factor of the glass, (Table F-1), and by the ratio of the glass area to the area of the opening in which the window is mounted. The value obtained is the initial value of the direct component of the illumination from the window, and does not take into consideration the daylight reflected from the walls and ceiling. For an appraisal of the effect of different ceiling and wall reflectances, see paragraph E-3. To obtain the in-service value, multiply the resultant illumination by the appropriate maintenance factor (Table III).

E-2.3—*Non-Uniform Source*—It has been shown that the brightness distribution of overcast skies can be approximated by a simple equation (Appendix C-4). This equation can then be applied to the general method for the calculation of the illumination from a rectangular source of any brightness distribution and new equations derived. Graphs of the results of this procedure are shown in Figs. E-5 and E-6 for the brightness distribution approximating an overcast sky. The results obtained from these curves when

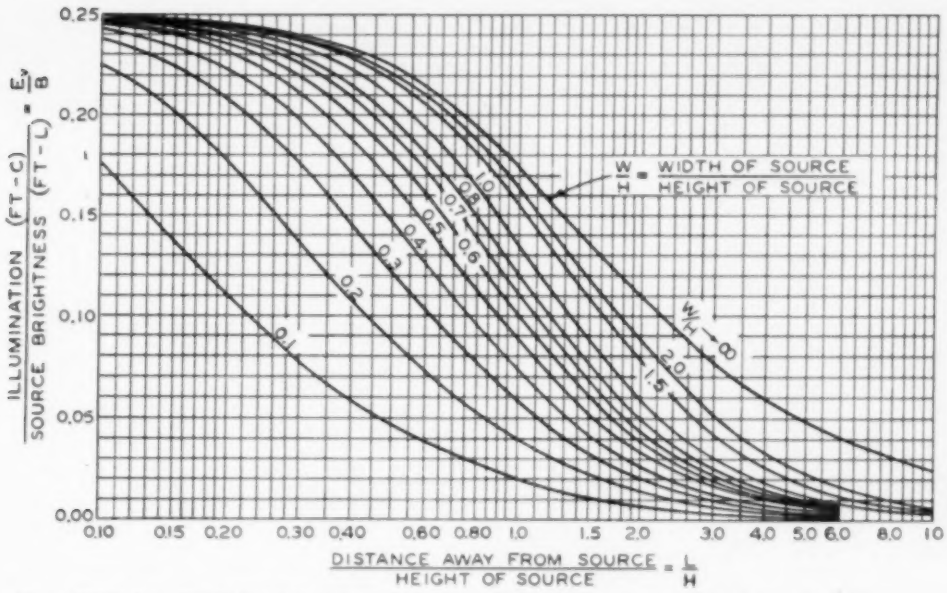
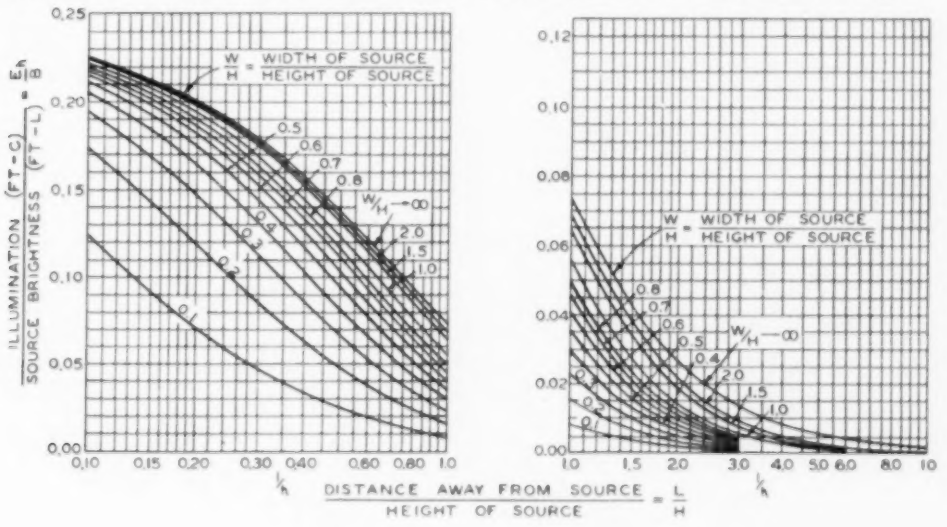

ILLUMINATION (FT-C) / SOURCE BRIGHTNESS (FT-L) = Ev/B
W/H = WIDTH OF SOURCE / HEIGHT OF SOURCE
W/H → ∞
DISTANCE AWAY FROM SOURCE / HEIGHT OF SOURCE = L/H

Figure E-3. Illumination from rectangular uniform source parallel to illuminated plane. (Ref. 109)

Figure E-4. Illumination from rectangular uniform source perpendicular to illuminated plane. (Ref. 109)


ILLUMINATION (FT-C) / SOURCE BRIGHTNESS (FT-L) = Eh/B
W/H = WIDTH OF SOURCE / HEIGHT OF SOURCE
W/H → ∞
DISTANCE AWAY FROM SOURCE / HEIGHT OF SOURCE = L/H

multiplied by the glass transmission factor. (Table F.I), the equivalent sky brightness, and the ratio of glass area to the area of the window give values which closely approximate test results for the conditions of dark walls and ceilings on an overcast day. The method of using these graphs is similar to that described in the preceding paragraph.

E-2.4—*Fenestra Method*— **(a)** A series of tables have been prepared based on coordination of mathematical formulae, test results, and field surveys which provide a rapid means for predicting natural lighting. (98, 118) The tables are based on standard window sizes using long rows of windows and are generally applicable to industrial installations or other conditions where long rows of windows are used. The values used in the tables are with an overcast sky brightness of approximately 1000 footlamberts; a window area decrease of 20 per cent for muntins, mullions, etc.; clean glass having a transmission factor of 85 per cent; and dark walls and ceilings. (See Tables E I, E II, and E III.) For any other brightness

condition, the results should be multiplied by the assumed brightness and divided by 1000. For example, from Table E II the illumination 35 feet from a single row of windows 6 feet 9 inches mounted 25 feet above the working plane, assuming a sky brightness of 1000 foot-lamberts, is 16 footcandles. The illumination for a sky brightness of 1200 foot-lamberts is 1200/1000 × 16 or 19.2 footcandles.

(b) A comparison between calculated illumination values by the use of the Fenestra Method, Table E I, (118) and calculated values obtained by the use of Moon and Spencer tables and graphs, Fig. E 4 (109) and by the Higbie Formula (92, 98) are given in Fig. E 7. The differences between these calculated values can be accounted for by the fact that the Fenestra Method is based upon test results using an artificial sky which was made up of a number of one-foot-high light boxes with a noticeable horizontal dark streak between adjacent boxes.

E-2.5—*Light Directional Glass Block*— **(a)** Table E IV presents panel brightness for a room fenestrated with light directional glass block above a vision strip of clear sheet glass. (139) This table gives these data for four latitudes and three conditions: summer solstice (June 21), spring and autumn equinoxes (March and September 21), and winter

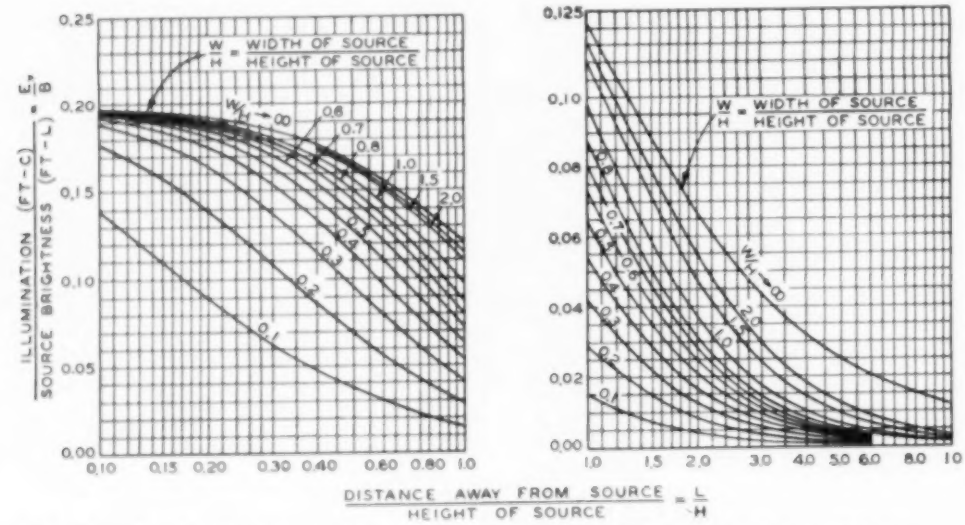
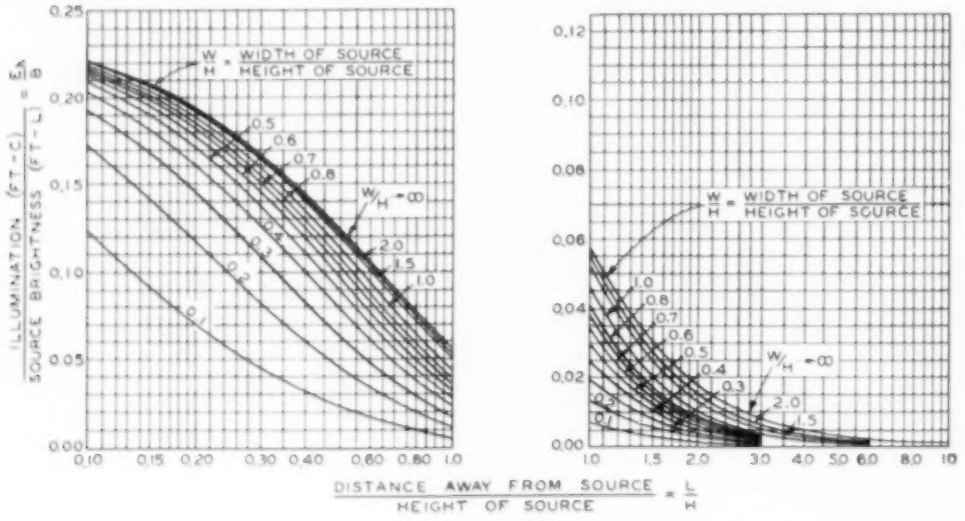

W/H = WIDTH OF SOURCE / HEIGHT OF SOURCE
ILLUMINATION (FT-C) / SOURCE BRIGHTNESS (FT-L) = E/B
DISTANCE AWAY FROM SOURCE / HEIGHT OF SOURCE = L/H

Figure E 5. Illumination from rectangular non-uniform source parallel to illuminated plane. (Ref. 109)

Figure E 6. Illumination from rectangular non-uniform source perpendicular to illuminated plane. (Ref. 109)


W/H = WIDTH OF SOURCE / HEIGHT OF SOURCE
ILLUMINATION (FT-C) / SOURCE BRIGHTNESS (FT-L) = E/B
DISTANCE AWAY FROM SOURCE / HEIGHT OF SOURCE = L/H

solstice (December 21). All the brightness data are for two positions of observation within a room. Position 1 is six feet from the plane of the glass block and position 2 is 18 feet from the plane of the panel. Both are 36 inches above the floor, and the observation point on the panel is nine feet above the floor. For position 1, the direction of view in a plane normal to the fenestration is 45 degrees above the horizontal; for position 2 it is approximately 20 degrees above the horizontal.

(b) Outlined below is the procedure for obtaining from Table E IV the task illumination 5, 12.5, and 20 feet distant from the fenestration in a room 24 feet deep, 32 feet wide, and 12 feet high. The ceiling reflectance is 70 per cent and that of the wall, 60 per cent. The fenestration, all mounted in one wall, consists of a 30-inch clear vision strip mounted 42 inches above the floor, and a six-foot panel of light-directional glass block.

(1) For the situation where the sun is shining on the glass block panel, divide the brightness of the panel as seen from position 2 by 5, 8 and 13 for the illumination in footcandles at distances of 5, $12\frac{1}{2}$, and 20 feet, respectively, from the panel.

(2) With no sun on the panel, for clear sky, divide the brightness of the panel as seen from position 2 by 1.5, 3.5, and 7 for the respective illuminations.

(3) For overcast sky divide the brightness of the panel as seen from position 2 by 1.5, 3.5, and 7 for the respective illuminations.

E-3—Effect of Ceiling and Walls.—**(a)** In daylighting, just as in artificial lighting, the ceilings and walls and floors reflect light to the working areas. The amount of light reflected from the interior surfaces when light colored walls, floors, and ceilings are used constitutes a large part of the total illumination on the working plane.

(b) For the case of clear glass, the daylight on the ceiling is for the most part reflected from the outside ground and depends, therefore, on the reflectance of the ground (Table E V). The direct component of daylight lighting of the sidewalls depends in part on the outside reflecting surface and the amount of sky visible from the point under consideration. For example, at a point on the sidewall near the ceiling, most of the light is reflected from the outside surfaces, while at a point near the floor most of the light is from the sky. High reflectance inside and outside surfaces increase the minimum illumination values and reduce brightness ratios in the field of view.

(c) In large buildings, such as factories, there are usually not many unobstructed surfaces to reflect the daylight. When the space is divided up by walls as well as in schoolrooms and offices, the daylighting reflected from the walls and ceiling is considerable. (47)

TABLE E-IV.—Brightness (Footlamberts) of a Panel of Light-Directional Glass Block. (121, 159)

Positions "1" and "2" are 36 inches above the floor and respectively six and 18 feet from the plane of the glass block; the observation point on the panel is nine feet above the floor; sky brightness measured at 15° altitude and 0° azimuth.

Time of Day*	Month	Clear Sky Southern Exposure			Clear Sky Eastern Exposure (Western Exposure)			Clear Sky Western Exposure (Eastern Exposure)			Average Overcast Sky All Exposures		
		Pos. 1	Pos. 2	Sky Brightness	Pos. 1	Pos. 2	Sky Brightness	Pos. 1	Pos. 2	Sky Brightness	Pos. 1	Pos. 2	Sky Brightness
34° N Latitude — Southern Plains													
8 AM	Dec. 21	280	290	1000	540	510	1200	30	40	400	30	35	240
	Mar. Sept. 21	250	260	1100	1130	1400	2900	45	55	600	75	90	590
(4 PM)	June 21	120	140	1600	1400	2000	3900	65	75	800	120	140	900
10 AM	Dec. 21	1000	1100	2000	380	400	1200	65	75	700	75	85	550
	Mar. Sept. 21	770	910	2000	800	970	1800	70	80	700	160	180	1200
(2 PM)	June 21	250	280	2200	1200	1700	2400	90	110	900	220	250	1700
	Dec. 21	1600	2400	3300	90	110	800	90	110	800	90	105	690
Noon	Mar. Sept. 21	1600	2500	2600	110	120	1000	110	120	1000	190	220	1450
	June 21	610	720	3100	130	160	1500	130	160	1500	340	390	2500
38° N Latitude — Central Plains													
8 AM	Dec. 21	220	230	900	390	420	900	25	30	300	25	30	210
	Mar. Sept. 21	240	260	1100	1100	1400	2900	45	55	600	75	85	550
(4 PM)	June 21	120	140	1100	1500	2200	4100	65	75	800	120	140	900
10 AM	Dec. 21	980	1100	1800	350	370	1100	60	70	700	65	75	480
	Mar. Sept. 21	860	1100	2000	740	870	1700	70	85	700	140	160	1000
(2 PM)	June 21	320	350	1800	1100	1600	2400	90	100	800	220	250	1700
	Dec. 21	1500	2500	3100	90	110	800	90	110	800	80	95	600
Noon	Mar. Sept. 21	1700	2800	2900	110	120	1000	110	120	1000	160	190	1200
	June 21	750	890	2500	130	160	1400	130	160	1400	320	370	2400
42° N Latitude — Central Plains													
8 AM	Dec. 21	170	180	630	270	280	700	20	25	300	15	20	140
	Mar. Sept. 21	280	300	1200	1200	1400	2900	55	65	600	75	80	500
(4 PM)	June 21	160	190	1100	1600	2200	4400	75	95	800	120	140	900
10 AM	Dec. 21	750	1100	1800	340	360	1100	65	80	630	55	65	410
	Mar. Sept. 21	950	1300	2100	740	840	1700	80	100	700	130	150	1000
(2 PM)	June 21	430	470	1800	1100	1500	2500	110	130	900	210	240	1600
	Dec. 21	1600	2500	2900	100	120	800	100	120	800	75	85	550
Noon	Mar. Sept. 21	1900	3300	3500	120	150	900	120	150	900	160	180	1200
	June 21	930	1100	2500	170	190	1400	170	190	1400	280	320	2100
46° N Latitude — Northern Plains													
8 AM	Dec. 21	100	110	400	185	160	400	10	10	100	10	10	70
	Mar. Sept. 21	270	280	1250	1100	1500	2800	45	55	600	65	75	480
(4 PM)	June 21	150	170	1100	1500	2200	4800	70	80	900	120	140	900
10 AM	Dec. 21	800	980	1700	280	290	1000	50	60	650	45	50	350
	Mar. Sept. 21	950	1250	2150	660	710	1650	70	85	700	110	130	800
(2 PM)	June 21	480	520	1800	1000	1300	2500	95	110	900	200	230	1500
	Dec. 21	1600	2200	2600	75	90	700	75	90	700	65	75	480
Noon	Mar. Sept. 21	1900	2800	3600	110	120	900	110	120	900	150	170	1100
	June 21	1100	1400	2700	140	160	1400	140	160	1400	250	290	1900

*AM time applicable eastern exposures and western exposures. For PM times for eastern exposures read down western exposures column, and vice versa. For example, the value of panel brightness for position "2" for 42° N Latitude for eastern exposure 2 PM, June 21 obtained from line 10, is 130 ft-L.

TABLE E-V.—Reflectances of Building Materials and Outside Surfaces.

Material	Reflectance (%)
Bluestone, sandstone	18
Brick	
light buff	49
dark buff	40
dark red glazed	30
Cement	27
Concrete	55
Granite	40
Marble (white)	45
Paint (white)	
new	75
old	55
Asphalt (free from dirt)	7
Earth (moist cultivated)	7
Granolite pavement	17
Grass (dark green)	6
Gravel	13
Macadam	18
Slate (dark clay)	8
Snow	
new	74
old	64
Vegetation (mean)	25

(d) Table E-VI, obtained from Figs. 1 and 2, gives the illumination on a horizontal plane from a window 12 feet high and 30 feet wide, mounted along one wall in a room 30 feet by 30 feet, for the condition of light and dark walls and ceilings. The values in this table indicate that near the back of the room where the direct light from the window is low, the total illumination may be brought up to three to four times the value of the direct component by the use of light colored walls and ceiling. The average per cent increase of the direct light from the side wall windows, resulting from the light colored walls and ceiling, is shown in column 4 of Table E-VI. It will be noted from this table that the uniformity of the illumination distribution is greatly improved when using light colored walls and ceiling, since the reflected light adds a greater percentage to the illumination in the back of the room than to the illumination near the windows. For the dark walls and ceiling, the ratio of the total illumination at a point 25 feet back from the windows to the illumination at a point five feet from the window is 9.1 to 1 as compared with a ratio of 3.2 to 1 for the case of the light colored walls and ceiling (reflectance 78 per cent).

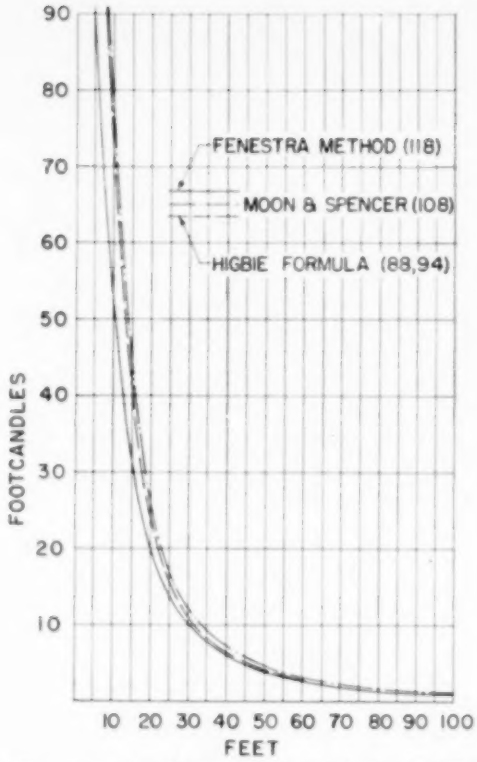


Figure E-7. Comparison of prediction methods: illumination for 8-foot high continuous window. Glass transmission 85%, window obstruction 20%, sky brightness 1000 footlamberts.

TABLE E-VI.—Illumination Distribution on a Horizontal Plane in a Room (30' x 30') With Light and With Dark Colored Walls. (40)

Window size: 12' high, 30' wide
Sky brightness: 314 ft-L
Maintained glass transmission: 77%
Ratio glass area to window opening: 83%
Light Walls and Ceiling Reflectance: 78%
Dark Walls and Ceiling Reflectance: 4%

Distance back from window (ft.)	Illumination (ft-c) dark walls and ceiling	Illumination (ft-c) light walls and ceiling	Increase as per cent of direct light from window
5	44	60	36%
10	28	43	60%
15	16	31	94%
20	9	24	167%
25	5	19	280%
Uniformity Ratio*	9:1	3.2:1	

*ratio of illumination at distance 5' and 25' from window

Appendix F

Light Diffusion and Transmission Data of Glass

F-1—*General* (a) The history of windows is related to the methods of protecting the window opening from wind, cold, and rain. A milestone in this history occurred about 1000 BC when glass, which had previously been valued only for its aesthetic character, replaced the older materials and admitted daylight, at the same time keeping the cold out. (206) Since that time, new manufacturing methods are continually being developed to expand the usefulness of glass.

(b) With the advancement of glass technology, the various properties of glass have been highly developed. Glass is now available with excellent heat absorbing, thermal insulating, sound absorbing, fire resisting, impact resisting and other properties. Whereas the complete description of the various types and properties of glass would fill a report of many volumes, the information presented herein is restricted to the light diffusion and transmission of glass as it affects daylighting.

F-2—*Types of Glass* — There are many different types of glass and glass block.

A description of several types of glass, as approved by the American Standards Association, August 12, 1941 is as follows: (ASA 42.1941)

Configurated glass is glass having a patterned or irregular surface. The surface configuration is usually applied during fabrication. Such glasses are not transparent and are somewhat light scattering. Glasses falling under this classification are often referred to as pebbled, stippled, rippled, hammered, patterned, chipped, crackled, cathedral, etc., depending upon the particular type of surface.

Mat-surface glass is glass whose surface has been altered by etching, sand blasting, grinding, etc., to increase the diffusion. Either one or both surfaces may be so treated.

Opal glass is highly diffusing glass having a nearly white, milky, or grey appearance. The diffusing properties are an inherent, internal characteristic of the glass.

Polished Plate glass is transparent glass whose surfaces have been ground and polished essentially plane and parallel.

Prism glass is flat glass into whose surface is fabricated a series of prisms, the function of which is to direct the incident light in desired directions.

Window glass (clear sheet glass) is transparent, relatively thin flat glass having glossy, fire-finished, apparently plane and smooth surfaces, but having a characteristic waviness of surface which is visible when viewed at an acute angle or in reflected light.

Glass block is a hollow, partially evacuated unit made of clear pressed glass, welded during manufacture, providing four surfaces on which designs may be pressed.

F-3—*Effect of Daylighting* — **(a)** The daylight illumination at any given point in a given room depends upon the amount of light transmitted by the glass in the window. A partial list of the transmission factors for various types of glass is given in Table F-I.

(b) The transmission factor is but one consideration in the choice of the glass type. Since low brightness ratios and good illumination distribution is the desired end result, it is necessary to consider also the effect of the glass upon brightness and distribution of illumination in the room.

TABLE F-I.—Transmission Data of Glass (203, 205, 209, 210).

Glass Type	Transmission Factor
Polished plate window glass	(83-89)%
Configurated glass	(70-88)%
Glass block	(60-80)%

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Recommended Practice of Daylighting

This report, the Society's first recommended practice on this important lighting subject, is available in booklet form with standard blue cover at 50 cents each to 4 copies; next 20, 25 cents each; all over 24, 15 cents each. Publications Office, Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Summary of Action Taken at Council Executive Meeting, New York

Highlights of the meeting of the Council Executive Committee held January 11 in New York, and action on the Society's regular business, are summarized below. Present at the meeting were: President C. H. Goddard, presiding; S. G. Hibben and Walter Sturrock, Vice-Presidents; E. M. Strong, Treasurer; A. H. Manwaring, General Secretary; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director; and G. R. Henninger, Editor, I.E.S. Publications.

Membership Statistics

First regular business of the meeting was the report on and election of new members. Favorable action on a report by the General Board of Examiners, E. M. Fahey, Chairman, resulted in the election of 26 Members, 82 Associate Members and 23 Student Members. Changes in membership figures since the start of the fiscal year are indicated in the following tabulation:

September 30, 1949		January 11, 1950
6863	Total Membership	7021
79	Members Emeritus	78*
44	Fellows	43
1321	Members	1360
5048	Associate Members	5110
244	Student Members	280

*Includes 6 Fellows of the Society

New Committees

In addition to further appointments to existing committees (an up-to-date list of which will be published later in the year) action was taken to refer for Council ballot the possible formation of a complete new committee to study television lighting. Subject to favorable action by Council, scope of the new committee will be: "To study and report on the lighting for (a) production of television programs and (b) for optical reception of television programs."

Another technical committee proposed for Council ballot was a Committee on Protective Lighting, principal purpose of which would be to review and revise the War Standards on Protective Lighting.

Sustaining Members

Three new Sustaining Members were added to the Society's roster by action on the report of George J. Taylor, Chairman of the Sustaining Members Committee. Elected were:

Cleveland Electric Illuminating Co.
72 Public Square
Cleveland 1, Ohio
Official Representative—R. C. Heaton

Hankins Container Co.
3044 West 106th St.
Cleveland 11, Ohio
Official Representative—R. T. White

Stone Manufacturing Co.
489 Henry St.
Elizabeth 4, New Jersey
Official Representative—Burt Wadams

Headquarters Staff Entertained

When the Executive Committee recessed for lunch, they had as their guests the entire headquarters staff, with the exception of two who were unable to attend. A buffet lunch was served at the Prince George Hotel, during which the committee and the staff became well acquainted. Headquarters staff members attending were: Janet Anthony, Nellie Arai, C. L. Crouch, Betty Dressor, Louise Dreyfus, C. E. Ellis, Beulah Faulkner, Eve Freyer, Geraldine Harvey, Jane Healy, G. Ross Henninger, A. D. Hinckley, Adelaide Jauch, Dan LaMothe, Muriel Merrifield, Rose Reda, Ruby Redford, Tina Rosen, Alice Stevens and Florence Tuebner.

British I.E.S. Plans Summer Meeting

What amounts to the National Technical Conference of the British Illuminating Engineering Society (London)—their I.E.S. Summer Meeting—has been scheduled for May 16 to 19 inclusive, at Buxton, England. The provisional program forwarded by the Society's Secretary, G. F. Cole, indicates a program of considerable interest to lighting engineers.

Mr. Cole extended his Society's invitation to overseas visitors to attend their conference, with no registration fee required for such visitors, and offering to arrange hotel accommodation.

Speaker of honor at this year's meeting will be Mr. Ivar Folcker of Sweden, who is one of the Vice-Presidents of the International Commission on Illumination.

Subjects covered will include a lecture on Visual Deception by Dr. L. A.

Regional Conferences

February 26-27, 1950	Southwestern Region	Dallas, Texas
March 6-7, 1950	Southern Region	Atlanta, Ga. Hotel Henry Grady
March 23-25, 1950	Pacific Northwest Region	Seattle, Wash. Edmond Meany Hotel
May 8-9, 1950	Great Lakes Region	Buffalo, N. Y.
May 11-12, 1950	Canadian Region	Montreal, Canada Mt. Royal Hotel
May 17-19, 1950	Midwestern Region	Philadelphia, Pa. Warwick Hotel
May 18-19, 1950	East Central Region	Milwaukee, Wis.

Sayce; a paper on Floodlighting, by R. O. Ackerley; Lighting of Fibre and Fabric, by H. Hewitt; Stage-Lighting in the Post-War Theatre, by L. G. Applebee; Street Lighting by J. M. Waldram.

A complete program of social events has also been arranged, including tours for visiting ladies, and a golf tournament for the Dow Golf Cup.

Home Lighting Course At New York University

Starting February 7, the New York University, Division of General Education, is offering an eight-week course in residential lighting, in cooperation with the I.E.S. New York Section Residence Lighting Forum. Course coordinator is Caroline E. Horn, chairman of the Forum's Educational Committee, and all of the lecturers are members of the New York Residence Lighting Forum.

Designed to be of practical value to interior decorators, or anyone interested in the residential environment, the course covers:

February 7 — The Language of Lighting, by Priscilla Presbrey, Westinghouse Electric Corp.

February 14 — Lighting Fixtures for Present-Day Homes, surface mounted and pendant, by Fred M. Wolff, Century Lighting, Inc.

February 21 — Lighting Fixtures continued — built-in, coves, wiring requirements etc., by Lillian Eddy, General Electric Co.

February 28 — Light for Visual Tasks in the Home; study, kitchen laundry, piano, by Lillian Eddy.

March 7 — Solutions to Specific Lighting Problems; examples of lighting in living room, dining room, bedroom, etc., by Myrtle Fahsbender, Westinghouse Electric Corp.

March 14 — Specific Lighting Problems, continued; television, art objects, gardens, holiday lighting, by Jan Reynolds, Sylvania Electric Products Inc., New York.

March 21 — Harmonizing Light and Decoration; examples of good lighting coordinated with room design. Modern lighting in traditional interiors, by Gladys Miller, Consultant.

March 28 — Color and Light; the effect of available light sources on decorator colors, textures, etc., by Don Caverly, Sylvania Electric Products Inc.

The Lectures include very practical how-to-do information, with cost calculations, and demonstrations of actual equipment. Free booklets and pamphlets, and lists of literature available are issued to all of the students.

University of Buffalo Features Lighting Course

University sponsorship of illumination courses formerly conducted solely by I.E.S. Sections and Chapters is a growing trend throughout the country.

A section of the newly relighted third floor at the L. Bamberger & Co. department store in Newark, N. J., scene of an I.E.S. New York Section dinner meeting and inspection tour January 11. Faced with a rigorously limited budget, a limitation of electric circuit capacity of 1200 watts per 22 x 28-ft bay, and the desire not to disturb the existing ceiling with its sprinklers and other hidden services, the architects, lighting consultants, and store management finally got together on the standard box-type fixture shown. Painted to match the ceiling, these 54 x 54 x 8½-inch fixtures really blend into the ceiling very unobtrusively when not themselves floodlighted for photographic purposes as in the above picture. Each fixture accommodates six 40-watt warmtone fluorescent lamps and is designed to accommodate also any foreseeable improvements in fluorescent sources. Egg-crate louvers are 2½ x 2½-inch, white. Center-line spacings are 11 and 14 feet to conform to bays, and yet give a reasonably even distribution of illumination, ranging from 20 to 30 footcandles, and averaging 24 ft-c on the merchandise. In the typical display cabinets shown at the rear, local supplemental lighting is provided by single lines of fluorescent (basically 40-watt) units behind valances. For accent lighting 150-watt reflector spots or floods are gymbal-mounted in the main fixtures, or swivel-mounted externally, as shown.

One such course recently completed was the six-lecture course on Advanced Lighting Design sponsored jointly by the University of Buffalo, Millard Fillmore College, and the Western New York Section of I.E.S.

Some 81 registrants completed the schedule which included Measurements of Lighting, How to Judge a Luminaire, Basic Design Methods, Egg Crate Ceilings, Built-In Lighting, and Cost Calculations.

Chicago Lighting Institute Installs Home Lighting Exhibit

The Chicago Lighting Institute now has open for inspection to the general public a series of rooms in which the staff can demonstrate home lighting principles and equipment. These rooms were installed in response to the numerous requests from architects, contractors and laymen who came to the Institute to see lighting equipment for homes they were designing, building or remodeling. The new display enables the Institute to show actual equipment in use to individuals and also to the many groups who attend the various lecture demonstrations.

The living-dining room can be used as a laboratory to demonstrate how a room appears with only incandescent or fluorescent or with a combination of both. All table and floor lamps are of the C.L.M. type. Incandescent lighting is provided from four two-filament table and floor lamps; from a ceiling fixture in the living room and one above the dining room table, with a lens in the bottom of the fixture, from two torchiers; from a recessed downlight; the painting is lighted from a recessed picture lighting unit. Fluorescent lighting is provided from a valance running the entire length of the room; from an eight-foot section luminous plastic cove and from cireline lamps in the table and floor portables.

Proper room illumination for the viewing of television can also be demonstrated by turning on either the table lamps on either side of the television set or by flooding the wall behind the television set with light from the valance, thus eliminating the severe contrast between the brightly illuminated screen and the dark adjacent areas.

The bedroom shows a four-foot section wall attached unit for reading in bed; downlighting from a continuous valance near the ceiling; lighting for the dressing table and a center ceiling fixture.

The ceiling fixture has in it a 32-watt cireline fluorescent lamp; one fifteen-watt fluorescent lamp on each side of the mirror and an RS type 250-watt ultraviolet sun lamp in an adjustable fixture above the mirror.

General lighting is obtained from a two-40-watt lamp, plastic louver bottom fixture; lighting for the work areas is produced from two alternate methods, one a U shaped valance and the other a straight valance over the sink; additional light for the work areas is obtained from under cabinet lights.

March 16, 1950 Deadline For Engineering Survey

March 15, 1950, has been announced as the closing date for the nationwide survey of selected engineering personnel now being sponsored by the Engineers Joint Council for the U. S. Office of Naval Research. To date over 60 per cent of the 115,000 questionnaires sent to full members of 18 national engineering societies have been answered.

A national asset, the body of facts gathered by the survey will be available to Government agencies, private industrial, educational and professional society planning groups, and for other legitimate purposes.

Those who have not yet answered the questionnaire are urged to do so before the March 15 deadline so that they may be listed among engineering resources of the nation. An interesting fact disclosed by the EJC is that although the first mailing of the ques-

Two views of the new home lighting exhibit at the Chicago Lighting Institute. At left, various designs for lighting the kitchen may be demonstrated. At right, the living room is equipped to show the effects of fluorescent lighting, incandescent lighting, or a combination of both.

tionnaire was 97,000 seniors engineers, these men gave the names of 18,400 other upper echelon engineers and recommended that they also be polled.

The survey was initiated as the result of a conference held in Washington late in 1948 attended by EJC representatives and those of many other engineering agencies, at which the need was discussed for a list of key engineers working in research, development and other scientific projects, who could be called in on a full or part time basis to work on the broad scientific programs of the National Military Establishment. The results of this survey are not to be construed, however, as an employment register.

Symposium on New Problems To Be Held by Connecticut Section

The Division of University Extension, University of Connecticut is cooperating with the Connecticut Section in offering a symposium covering "Recent Problems in Illuminating Engineering," which is to be presented at the auditorium of the Hartford Electric Light Company in Hartford, Connecticut in February, March and April of this year.

The symposium will consist of ten lectures arranged as follows:

Wednesday, February 15. W. S. Plymale, Jr. — "Photometric Measuring Devices and Methods."

Tuesday, February 21. G. S. Evans — "Electrical and Light-Output Characteristics of Gas-Filled Light Sources."

Wednesday, March 1. Daniel Smith — "Colors and Surface Finishes of Materials."

Wednesday, March 8. Lt. Commander Dean Farnsworth — "Vision and Illumination."

Wednesday, March 15. Phelps Meaker — "Visual Comfort in Relation to Brightness and Glare."

Wednesday, March 22. Willard Allphin — "Possible Criteria for Good Lighting."

Wednesday, March 29. Miss D. E. Spencer — "Luminous Ceiling Lighting."

Wednesday, April 5. H. R. Condit — "Photographic Exposure in Daylight."

Wednesday, April 12. Val Roper — "Problems in Automotive Lighting."

Wednesday, April 19. Miss Priscilla Presbrey — "New Definitions and Terminology in Illuminating Engineering."

Originated by the Educational Committee Connecticut Section, the Symposium is expected to bring forth the most recent advances in the science and art of illumination, with emphasis on the newer viewpoints. The IES Lighting Handbook will serve as basic reference in the series for purposes of unity. Dr. G. S. Timoshenko of the University of Connecticut is serving as technical consultant with regard to coordination of lecture contents.

Cash Awards to be Made For Farm Electrification

Five cash awards, amounting to $1,000 and five engraved plaques, known as the Frank Watts Awards, will be made annually by *Farm Journal* magazine to stimulate farm electrification, according to an announcement by Graham Patterson, publisher of the magazine. Cash prizes of $300, $250, and three of $150 each will go to the farm departments of electric operating organizations, while the plaques will be awarded to the winning companies. The plaques will read "For excellence in promoting farm electrification as a productive force for better farming and better living."

Identifying these as the Frank Watts Awards followed a suggestion by a group of electric service men interested in the farm field, and is belated honoring of the man who is said to have contributed more to the furthering of farm electrification than any other individual. The writings and speeches of Frank Watts are widely known throughout the electrical industry, in which he has been employed for the past forty-three years. He is widely recognized as the foremost authority in the field of farm electrification. For the last nine years he has been associated with *Farm Journal* magazine, where he has devoted his entire time and attention to the advancement of the use of electricity in the farm home and for farm work.

The Edison Electric Institute, New York, will administer the awards, which will be presented for the first time in April, 1951, for work done in 1950. Entries will close at the offices of the Institute on February 1, 1951.

Copies of the Rules and Regulations governing the contest may be obtained from E.E.I., 420 Lexington Ave., New York, N. Y.

Ideas From Other Sections

For the past several years a Local Activities Conference has been held, usually in New York in June, for the purpose of exchanging ideas between different Sections and Chapters, and between outgoing and incoming officers. Many of the ideas originating at this Conference are being successfully practiced in a number of Sections. A few more have turned up since. Would any of the following local practices work in *your* Section?

Local "Newspapers"—Regular mimeographed, strictly local news bulletins are issued by several Sections and Chapters, creating a strong sectional bond of *all* local members. Cleveland Section has its four-page folder *The Lumen Press*, "Official Organ of the Cleveland Section" according to the masthead. Chicago Section puts out a printed job, *Lumenews*. Other local publications are the *Indiana Chapter News;* Mother Lode *News Bulletin;* Utah Chapter INEWS, to name a few.

These mimeographed publications usually inform members of what's doing locally in lighting—what's coming in their own programs—give personal news—outline abstracts of talks given—give instructions for data sheet preparation—spot lighting jobs worth visiting, etc., etc. By photo-offset process, some even have pictures.

Some Sections carry out the same idea on one page of their meeting notices, especially when these are four-page folds.

Informal Luncheon — New Orleans Section members favor a plan of holding informal weekly luncheons where members, their friends and associates can meet for social or business discussions. No reservations, no program—and no planned menu. They all like the idea—attendance is high.

Contests — The idea of an inter-Regional contest on "My Most Interesting Lighting Job," originating last year in the East Central Region, is not only being repeated there, but has spread to several other Sections.

Local Conferences—Quite apart from the big Regional Conferences, some Sections and Chapters conduct one-day lighting conferences, one to four times a year. Such meetings bring in outlying members of the Section, nonmembers and other industries. They stimulate interest in lighting, and

LIGHTING CALENDAR

Society Events

February 8, 1950 — Meeting of I.E.S. National Council, New York, N. Y.

February 26-27, 1950 — Southwestern Regional Conference, Dallas, Texas.

March 6-7, 1950 — Southern Regional Conference, Atlanta, Ga., Hotel Grady.

March 23-25, 1950 — Pacific Northwest Regional Conference, Edmond Meany Hotel, Seattle, Wash.

April 6, 1950 — Meeting of I.E.S. Council, Edgewater Beach Hotel, Chicago, Ill.

May 11-12, 1950 — Canadian Regional Conference, Mt. Royal Hotel, Montreal, Que., Canada.

May 17-19, 1950 — Midwestern Regional Conference, Milwaukee, Wisconsin.

May 18-19, 1950 — East Central Regional Conference, Warwick Hotel, Philadelphia, Pa.

May 22-23, 1950 — Great Lakes Regional Conference, Buffalo, N. Y.

June 7, 1950 — Meeting of I.E.S. National Council, New York, N. Y.

August 21-25, 1950 — Southern California National Technical Conference, Hotel Huntington, Pasadena, Calif.

Industry Events

February 6, 13, 20, 27, March 6, 13, 20, 27, 1950 — Essex Electrical League, 5th Annual Light and Power Conference, Public Service Building, Newark, N. J.

February 6-9, 1950 — National Electric Sign Association Convention and Exhibit, Netherland Plaza, Cincinnati, Ohio.

February 16-17, 1950 — National Adequate Wiring Bureau, 6th Annual Adequate Wiring Conference, Hotel Statler, St. Louis, Mo.

February 27, 28, March 1, 1950 — Annual Joint Convention Association of Municipal Electric Utilities, and the Ontario Municipal Electric Association, Royal York Hotel, Toronto, Canada.

February 27 - March 3, 1950 — American Society for Testing Materials, Committee Week and Spring Meeting, Hotel William Penn, Pittsburgh, Pa.

March 3, 1950 — Association of Electrical Construction Engineers, Annual Meeting, 2 Park Ave., New York, N. Y.

March 7-10, 1950 — Essex Electrical League, 6th Annual Electrical Industrial Exposition, Newark, N. J.

March 8, 1950 — Annual Meeting, Inter-Society Color Council, Hotel Statler, New York.

March 13-16, 1950 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

March 26-31, 1950 — Greater New York Safety Council, 20th Annual Safety Convention and Exposition, Hotels Statler and Governor Clinton, New York, N. Y.

April 4-6, 1950 — Edison Electrical Institute, 16th Annual Sales Conference, Edgewater Beach Hotel, Chicago, Ill.

April 5, 6, 7, 1950 — 12th Annual Midwest Power Conference, Sherman Hotel, Chicago, Ill.

April 17-18, 1950 — Annual Conference, Canadian Electrical Distributors Association, General Brock Hotel, Niagara Falls, Ont.

April 19-22, 1950 — The Electrochemical Society, Ninety-seventh Convention, Statler Hotel, Cleveland, Ohio.

May 15-18, 1950 — National Fire Protection Association, 54th Annual Meeting, Haddon Hall, Atlantic City, N. J.

June 6-9, 1950 — Edison Electrical Institute, 18th Annual Convention, Atlantic City, N. J.

June 13-16, 1950 — American Institute of Electrical Engineers, Summer General Meeting, Pasadena, Calif.

June 13-16, 1950 — National Association of Electrical Distributors, Atlantic City, N. J.

June 15-19, 1950 — 60th Annual Meeting, Canadian Electrical Association, Murray Bay, Quebec.

August 7-19, 1950 — First United States International Trade Fair, Chicago, Ill.

Street Lighting Forum New England Section

The New England Section turned one of its recent regular meetings into a highly educational forum on street lighting. With six specialists in this field on the program, members of the Section were, in effect, treated to a first-class course on street illumination, with emphasis on fluorescent as a source. Papers presented at the forum were:

Review of Street Lighting Developments Since the War, Including Fluorescent—by C. H. Rex, General Electric Co., Lynn, Mass.

Application Techniques for Fluorescent Street Lighting—by R. M. Sweitzer, General Electric Co., Lynn, Mass.

Can We Afford Fluorescent Street Lighting?—by J. P. Rutherford, General Electric Co., Lynn, Mass.

Sealed Beam Fixtures for Residential Street Lighting and Low Mounted Fluorescent Bridge Lighting—by R. G. Stauer, Sylvania Electric Products Inc., Salem, Mass.

Unique Lighting on New Mystic Bridge—by F. P. Coffey, Anderson Coffey Co., Inc., Boston, Mass.

Comments on the Foregoing Talks from the Point of View of a User of Lighting Equipment, and a Report on Economics of Mercury Versus Incandescent Street Lighting—by J. W. Young, New England Power Co., Boston, Mass.

S.M.P.E. Changes Name

Effective January 1, the name of the Society of Motion Picture Engineers was officially changed to the Society of Motion Picture and Television Engineers. Outstanding among the reasons for the change, as announced by Earl I. Sponable, President of the Society, was the increasing mutual interests of technical people in both motion pictures and television, as well as the Society's active participation in the development of new television techniques.

In addition, the Society has filed a brief with the Federal Communications Commission proposing specifications for a nationwide theatre television system.

Unusual Subjects for I.E.S. Local Programs

That attendance at I.E.S. Section and Chapter meetings is highly educational is evident from the more or less specialized subjects being featured on the programs. For instance,

CAPITAL SECTION — The Color Symposium at the French Lick Conference was one of the meeting's most popular features. Continued interest in

offer opportunity for gaining new members. Iowa Section, for instance, has held four conferences each year for many years now. Other Sections practice a similar idea with symposiums on specific phases of lighting application.

Meeting Notices — A tear-off return card forms a part of the Rochester Chapter notice.

Quebec Chapter notices, written in both French and English, are accompanied by an interesting letter each month from the Chairman of the Program Committee.

Eastern Pennsylvania, Georgia Section, Puget Sound, New Orleans, and several others, incorporate hand-done art work, varying from the sublime to the funny, but in either case, eye-catchers. Puget Sound uses art (?) decorated teaser notices to catch attention, each building up to the final punch notice of the actual meeting. Nobody, but nobody, could say he hadn't seen them!

Pittsburgh Section pointed up a special All-Industry Banquet by printing the notice on a blotter.

Oregon Section lists its past-chairmen on its notice — a nice gesture to these valuable members.

Montreal Section reserves one portion of its notice for Coming Events.

Inspection Trips — This type of meeting is now almost universal, but they have grown from inspection tours of local installations to, in some cases, motor cavalcades to spots a hundred miles away. Unique subjects are inspected in many cases. For instance: New York Section toured the *Ile de France* luxury liner featuring outstanding lighting. Connecticut Section inspected a submarine, and another time an aircraft engine plant. Milwaukee Chapter formed a parade to visit three remodeled schools in outlying towns, winding up at Whitefish Bay Inn for an evening of fun.

color seems everywhere indicated. The Capital Section, for one, held a recent meeting on "Color Terms and Concepts" by Dr. D. B. Judd, U. S. Bureau of Standards, and "Some Aspects of Vision and Illumination," by Ralph M. Evans of Eastman Kodak.

The techniques of Lighting a Television Studio, is a brand new subject for I.E.S. meetings. Capital Section presented this topic on December 8. So did New England Section, Northern California, and Southwestern Section.

CENTRAL NEW YORK CHAPTER — While the lighting of churches and large public buildings may not come up as an every day problem, wide interest in the subject has been noted. Central New York Chapter in Syracuse treated its members to an expert's views on the subject at its January meeting.

CHICAGO SECTION — At the Local Activities Conference last June, it was recommended that every Section and Chapter hold at least one program on home lighting. Many of them are. Chicago Section, for instance, featured three speakers on Residential Interiors at a recent meeting — with a specialist on three different phases of this subject — Design, Color, and Light.

CLEVELAND SECTION — "Trends in Service Station Lighting," another specialized phase of lighting practice, and highly educational, was presented in Cleveland January 3, as a Technical Forum open discussion.

MILWAUKEE CHAPTER discussed a subject not frequently presented — "Lighting for Outdoor Recreation and Safety."

MONTREAL SECTION — Inspiration on the importance of lighting to the general welfare has occasionally been found to be an excellent subject for I.E.S. meetings. Montreal Section invited Dr. E. A. Atkinson of the Industrial Health Division, Department of Welfare, Ottawa, to speak on "Illumination as Confined to Certain Aspects Related to Health."

OREGON SECTION is among the several sections in which "Information Please" programs are popular. A return engagement by popular demand was made of their successful quiz program recently with a leading member as quiz master.

PITTSBURGH SECTION devoted a meeting to "Radiation Measuring Instruments." The meeting furnished a

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ABOUT PEOPLE

Dr. Matthew Luckiesh, recently retired from the General Electric Co. Lighting Research Laboratories, Nela Park, has been appointed Director of Research and Development for the Foster & Davies, Inc., advertising agency.

W. G. Darley and **A. T. Moses** of Austin, Texas, have announced the formation of Darley & Moses—a firm of consulting engineers at 208 West 18th St., Austin.

W. A. Hill has been named general manager of the Burndy Canada Ltd., Toronto, Ontario. Mr. Hill was formerly general manager of Noma Electric Co. of Canada. Other appointments announced recently by the company were **Bryce W. Keil**, as district sales manager covering Quebec and the Maritime Provinces; **Roy Bunston** named chief sales engineer; and **Al Thomson** appointed sales engineed for Ontario.

E. E. Weyeneth joined the staff of *Engineering News Record*, McGraw-Hill publications, on February 1, to undertake a study of marketing problems in the construction field.

The National Association of Electrical Distributors has announced the addition to their headquarters staff of **J. G. Johennesen** and **Philip M. Pritchard**. Mr. Johennesen will serve in a special consulting capacity and Mr. Pritchard will be a special representative of the Association, traveling through the country.

Earl H. Aik of Milwaukee, Wisconsin, and his associate **Robert Aik** of Appleton, Wisconsin have been appointed to represent Silvray Lighting Inc. and Vision Aids Products in Wisconsin, effective January 1. Silvray also has recently added Paul H. Krasner to its staff at New York and Bound Brook, N. J.

Fred F. Harroff, general manager of the General Electric Company's Lamp Department at Nela Park, Cleveland, Ohio, has been elected a vice-president of the company. Mr. Harroff, who will retain his position as general manager, succeeds **Martin L. Sloan**, whose retirement effective December 31 was announced recently.

Ralph R. Cheney has been appointed manager of a newly created Milwaukee Lamp Sales Division of the Westinghouse Electric Corp., Lamp Division, according to a recent announcement. For the past six of his 24 years with Westinghouse, Mr. Cheyney has been Chicago metropolitan manager for the Lamp Division, and is currently chairman of the Chicago Section of I.E.S.

Harold D. Blake, technical director of the Lamp Development Laboratory at Nela Park, retired December 31 after more than 40 years of continuous service. Mr. Blake has been technical director of the laboratory for the past 30 years, having been one of the five original staff members. He has been responsible for technical work involved in the development of new light sources.

Paul F. Stiller, a former lighting specialist with the West Penn Power Co. in Pittsburgh, has been named manager of the Cleveland office of the Pittsburgh Reflector Co., according to B. D. Levaur, vice-president.

Dr. Karl B. McEachron of Pittsfield, Mass., an internationally recognized authority on lighting, has been awarded the 1949 Edison Medal, top A.I.E.E. award. The Medal, given annually since 1909 to outstanding electrical engineers and scientists, was presented to Dr. McEachron, manager of engineering, Transformer and Allied Product Divisions of General Electric Co., Pittsfield, at the Winter Meeting of the American Institute of Electrical Engineers held in New York at the Hotel Statler, January 30 - February 3.

Retirement of **Donald H. Wyre**, manager of the Allegheny Sales District of General Electric's Lamp Department, and appointment of **Warren P. Thayer** as his successor, were announced recently by Fred F. Harroff, general manager of the department.

N. H. (Nap) Boynton, sales consultant in the administrative staff of General Electric Co., Nela Park, Cleveland, Ohio, retired December 31 after more than 40 years' service.

Frank L. Taylor has been appointed manager of the newly created Midwest Lamp Sales Division of the Westinghouse Electric Corp., with headquarters in Kansas City, Mo. Mr. Taylor has been branch manager for Westinghouse in Kansas City, and was formerly a lighting engineer with the Kansas City Power and Light Co.

Rene M. Moisson of Cambridge, Mass. has been named New England representative for the Edwin F. Guth Co. Mr. Moisson will cover Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island, from offices at 71 Prentiss St., Cambridge.

Frank Moos, formerly manager of the Lighting Sales Department of Graybar, has been appointed Edwin F. Guth Co. representative in Maryland, Virginia and District of Columbia. Mr. Moos' headquarters will be Washington, D. C.

OBITUARY

J. Carl Fisher

The Society has learned with regret of the sudden death on January 10 of J. Carl Fisher, until recent years one of its most active members. At the time of his death, Mr. Fisher was Manager of the Customer Relations Dept. of the Consolidated Gas and Electric Light and Power Co., Baltimore, Maryland, his business connection since 1919.

For nearly 30 years, Mr. Fisher was a member or chairman of numerous I.E.S. committees, seldom less than five every year. He served also as a Director of the Society for two consecutive terms of three years each, and was Chairman of the Baltimore Chapter in 1928-1929, and again in 1933 to 1935 for two more terms. Mr. Fisher was also appointed twice to the Papers Committee in which capacity he reviewed many technical papers for publication in the Transactions. Several of his own papers appeared in the earlier issues, covering notably his work in the lighting of generating stations.

Born in Maryland in 1893, Mr. Fisher attended Washington and Lee College and Massachusetts Institute of Technology, of which he was Honorary Secretary.

Louis G. Boomsma

Louis G. Boomsma, proprietor of Luminous Tube Sign Co., of Paramus, N. J., and long-time member of the New York Section, died at his home there recently.

Born in Holland in 1899, Mr. Boomsma came to this country 29 years ago. Before establishing his own firm for research on and manufacture of luminous tubing in 1930, he was connected with the American Neon Light and Sign Co., New York, in charge of their testing and experimental laboratory.

Local Meetings

Continued from page 145

one-night course in methods and techniques of properly handling radiation measurement instruments and their application. Pittsburgh Section also is apparently following advice brought out at the Local Activities Conference to acquaint all members with what the Society has to offer. Their December meeting was on "I.E.S. Dividends," with demonstrations of standards, publications and other services.

Quebec Chapter offered "Explosion Proof Lighting Fixtures," a rather unique topic. With the Quebec meeting notices, incidentally, one has a choice of reading in either French or English, information being in both languages for this only bilingual I.E.S. Chapter.

St. Louis Section—A different type of quiz program was their "The Answer Man" meeting. F. I. (Tug) Wilson of F. W. Wakefield Brass came equipped to answer informally questions on all phases of lighting problems, and the function and operation of I.E.S. Very successful.

Southern California Section—A symposium on "Requisites for Good Seeing" featured ten speakers at a recent Southern California Section meeting. With leading experts on each subject, the symposium covered — Physical Environ — Posture — Photometry — Refraction — Illumination Design — Vision Training — Luminaires — Modern Lenses. The Symposium was held as a joint meeting with the American Optometric Association.

South Texas Section — Not many illumination courses teach "What Color Fluorescent Lamp to Use for a Particular Application." To South Texas Chapter members, this is now no problem. Their program on November 21 covered the subject thoroughly, with George Trotter leading the discussion.

Southwestern Section — "Phychology of Color" — by E. L. Aten, M.D., was offered by this Section on January 16. Dr. Aten's talk was in keeping with the modern trends in lighting which embrace many ramifications heretofore overlooked.

Spare Copies of Transactions Needed at I.E.S. Headquarters

The headquarters stock on certain issues of Illuminating Engineering is now very low. If any members have extra copies of the following numbers, the I.E.S. office would be happy to receive them. Copies addressed to A. D. Hinckley, Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y. would be gratefully received. Those needed are:

1940 November
1942 January-February
1943 February
1944 September
1945 November
1947 January

IT SEEMS TO ME

Lighting Education

To the Editor:

Mr. R. G. Corak's letter concerning Lighting Education (January, 1950 issue of Illuminating Engineering, p. 75) has much of merit in it, and I am very happy to see his point of view. Needless to say the matter is rather complicated and is one of a series of problems which has been under consideration by the I.E.S. Committee on Professional Requisites for some time.

In final analysis I think he will find that the Engineering Schools will offer such courses (illumination) as they feel there is a sufficient demand for them. However, schools are just like

any other business and there must be a sufficient demand for the product to justify the necessary capital expense for setting up the equipment to turn out the product. While one may not think of graduate engineers as products, the process is in some ways similar to industrial production, and can be analyzed by very much the same techniques. . . .

As Chairman of the Committee on Professional Requisites, I will certainly bring up the matters he has discussed. . . . — R. L. Biesele, Jr., *Professor, Electrical Engineering, Southern Methodist University, Dallas, Texas.*

NEW MEMBERS

At the meeting of the Council Executive Committee held in New York City on January 11, 1950, the following were elected to membership:

Baltimore Chapter

Associate Member:
Kahn, F. L., Garden City Plating & Mfg. Co., Baltimore, Md.

Carolinas Chapter

Members:
Dagenhardt, E. V., The Gordon Wells Co., Charlotte, N. C.
McPherson, W. P., Carolina Power & Light Co., Raleigh, N. C.
Smith, F. F., General Electric Co., Charlotte, N. C.
Tysinger, P. T., Duke Power Co., Charlotte, N. C.

Associate Members:
Helfrich, R. B., General Electric Supply Corp., Raleigh, N. C.
Norris, E. J., Duke Power Co., Charlotte, N. C.

Chicago Section

Associate Members:
Coleman, L. J., Solar Light Mfg. Co., Chicago, Ill.
Heale, E. S., Sylvania Electric Products, Inc., Chicago, Ill.
Sorensen, E. M., Sylvania Electric Products, Inc., Chicago, Ill.

Student Members:
Ford, D. E., Jr., University of Illinois, Urbana, Ill.
Rosenstein, Arthur, University of Illinois, Urbana, Ill.
Tarnoff, N. H., 1624 S. Trumbull Ave., Chicago, Ill.

Central New York Chapter

Associate Member:
Crosby, W. F., Jr., Corning Glass Works, Corning, N. Y.

Student Members:
Barton, G. H., Cornell University, Ithaca, N. Y.
Hastings, Warren, Cornell University, Ithaca, N. Y.

Cleveland Section

Members:
Gavitt, H. A., The Ohio Power Co., Fremont, Ohio
Green, R. N., The Wagner-Green Co., Cleveland, Ohio
Ingraham, H. E., Holdenline Co., Cleveland, Ohio

Associate Members:
Brumbaugh, K. D., Lewis Laboratory, National Advisory Committee for Aeronautics, Cleveland, Ohio
Kaseman, E. O., Westinghouse Electric Corp., Cleveland, Ohio
Rodgers, R. C., General Electric Co., Nela Park, Cleveland, Ohio

Student Members:
Mitchel, K. O., Case Institute of Technology, Cleveland, Ohio
Morelli, A. R., Case Institute of Technology, Cleveland, Ohio
Panke, H. E., Case Institute of Technology, Cleveland, Ohio
Wood, T. J., Jr., Case Institute of Technology, Cleveland, Ohio

Connecticut Section

Members:
Ouellette, V. J., Hartford Electric Light Co., Hartford, Conn.
Shallenberger, J. W., 886 Main St., Bridgeport, Conn.

Eastern Pennsylvania Chapter

Member:
Jac, David, Neuburg Sales Service, 103 Park Ave., New York, N. Y.

Associate Member:
Butler, M. J., Jr., Jno. E. Graybill & Co., York, Pa.

Florida Chapter

Associate Members:
Holtsinger, E. M., General Electric Co., Tampa, Fla.
Neuman, N. L., Nicholas L. Neuman & Associates, Tampa, Fla.

Georgia Section

Associate Member:
Branham, V. H., Jr., Verlyn H. Branham Co., Atlanta, Ga.

Heart of America Section

Associate Members:
Groh, H. S., Evans Electrical Construction Co., Kansas City, Mo.
Meier, V. A., The Wiremold Co., North Kansas City, Mo.
Razak, G. E., Kansas Power & Light Co., Lawrence, Kan.
Tholl, L. T., Floyd's Electrical Supply Co., Kansas City, Mo.

Iowa Section

Associate Members:
Sandy, F. R., Electro Mfg. Co., Des Moines, Iowa

Student Members:
Duffy, James M., Iowa State College, Ames, Iowa
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Continued on page 21A

NEW EQUIPMENT DATA
AVAILABLE WITH COUPON

New manufacturers' catalogs and bulletins listed below are available free to readers of ILLUMINATING ENGINEERING by mailing the coupon. Circle the numbers of those items in which you are interested and drop in envelope addressed to Publications Office.

Offer good for two months.

1 Industrial glass Bulletin 1e2 about custom made glass products, covers physical properties of glass including durability, color, beam control, and light transmission. Kopp Glass Inc., Swissvale, Pa.

2 Bulletins in series feature individual illustrated booklets each giving complete specifications and technical data about this line of fluorescent and incandescent lighting fixtures for commercial and other installations. Curtis Lighting Inc., Chicago, Ill.

3 R.L.M. Specifications book contains detailed specifications for 14 commonly used incandescent and fluorescent lighting units, covering materials, shielding and brightness, construction, reflection factor, photometric performance, etc. R.L.M. Standards Institute, Chicago, Ill.

4 Custom-built cold cathode folder contains design suggestions, construction data, technical information, photographs and locations of leading installations. Federal Enterprises Inc., Chicago, Ill.

5 Pocket Catalog, 32 page condensed listing of fluorescent and incandescent commercial and industrial lighting fixtures, containing specifications, technical data, installation methods. Edwin F. Guth Co., St. Louis, Mo.

6 Maintenance manual, 24 page pocket size manual presents advantages of good lighting, factors of good illumination and suggestions regarding fixture care, maintenance and operation. Champion Lamp Works, Lynn, Mass.

7 Cold cathode catalog shows examples of commercial, industrial and show case installations, including physical and lighting specifications for fixtures and lamps. Mobrco Inc., Watertown, Mass.

8 "Over-All Lighting" new 40 page catalog showing line of luminaires for schools, offices, drafting rooms and stores, including technical data, installation and maintenance operations, complete description of each fixture. Catalog No. 50. F. W. Wakefield Brass Co., Vermilion, Ohio.

9 "Benjamin Lighting Equipment for Industry and Commerce," 40-page bulletin AD 5596 illustrates and describes most widely used Benjamin lighting units including "Sky-Glo" Luminous Louvered System. Benjamin Electric Co., Des Plaines, Ill.

10 "Powerstat Light Dimming Equipment for Churches" describes in 8-page booklet the principles behind the dimming equipment, its adaptability to custom installations, and specifications for various types. Superior Electric Co., Bristol, Conn.

11 Lighting application and layout design, with ordering and construction information on Commercial, Industrial and Floodlighting equipment is featured in the condensed 100-page catalog CIF-61-030. Westinghouse Electric Corp., Cleveland, Ohio.

12 "Planned Lighting for Modern Stores" 12 page illustrated booklet describes recent store lighting installations in many sections of the country, gives description of jobs, and explains function of lighting for selling efficiency. Pittsburgh Reflector Co., Pittsburgh, Pa.

13 "Glass Block Job Data" 4-page folder reports on illumination and brightness surveys conducted in classrooms of Detroit elementary school with glass blocks installed in continuous panel above clear vision strip. Pittsburgh Corning Corp., Pittsburgh, Pa.

14 Module fixtures. 20 page booklet contains information about "modular system" of lighting, embodying principle of uniform lighting units which can be combined for a custom-fitted pattern lighting system. Gives specifications and construction details. Mitchell Mfg. Co., Chicago, Ill.

15 Floodlighting Catalog No. 2100 in 35 pages gives descriptive information on various sizes and types of floodlights and auxiliary equipment, includinging dimensions and specifications. Pyle National Co., Chicago, Ill.

16 Plan-O-Lite packet is a reference file of sample engineered lighting layouts, engineering data and photographs for eight different bank and commercial installations. Frink Corp., Long Island City, N. Y.

17 Catalog No. 90 contains this company's complete line of street and highway lighting equipment, dimensions and data necessary for planning average installations, and shows as well lighting equipment for gasoline stations, and floodlighting. Philadelphia Electrical & Mfg. Co., Philadelphia, Pa.

18 Bulletins 10-E-1, 10-M, 30-A-3, feature respectively "Lenox" and "Luvex" fluorescent and slimline fixtures; and industrial fixtures, including specification and illumination data. Day-Brite Lighting Inc., St. Louis, Mo.

19 Street lighting catalog in elaborate loose-leaf binder shows complete line of luminaires for street and highway lighting, including an engineering handbook section containing information as to language, purpose, visibility, measurements and other data essential to engineers. Westinghouse Electric Corp., Cleveland, Ohio.

20 Plastic extrusions with their specifications, properties and other technical data are included in catalog which shows this company's manufacturing techniques, completely illustrated application ideas and other information. Sandee Mfg. Co., Chicago, Ill.

21 Fixture hangers, 24 page Bulletin No. 500 describes all purpose equipment for hanging of lighting fixtures and other equipment on the job. Includes shapes, sizes, installation methods, and some typical jobs. Unistrut Products Co., Chicago, Ill.

22 Transformers and their applications for fluorescent and cold cathode lighting are shown in loose-leaf bound series of Engineering Service releases illustrating typical installations of all types, and presenting technical data about each. Acme Electric Corp., Cuba, N. Y.

23 New technical catalog sections show photographs and drawings of a wide range of typical installations of disconnecting and lowering hangers for lighting equipment, are available to those engaged in lighting design and specification. Thompson Electric Co., Cleveland, Ohio.

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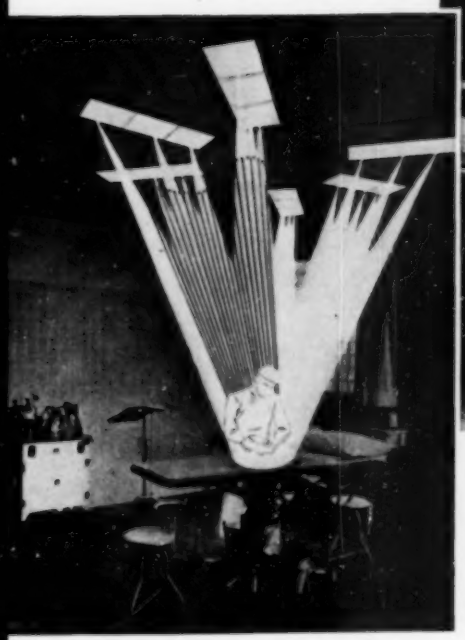

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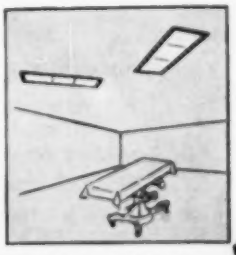
Sketch showing Holophane Emergency or Minor Surgery System



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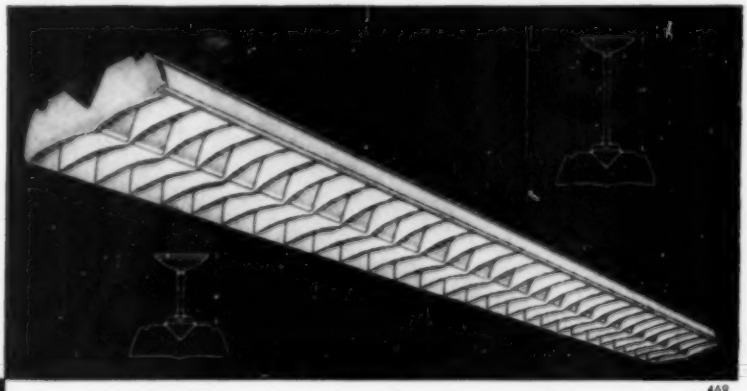

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For two 96" T-12 Slimline lamps, single unit or continuous installations. For suspension mounting, listed with 8" and 28" "A-J" Adjustable hangers.

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Once in a blue moon, a truly great fixture makes its appearance. Now, after years of research and designing, the matchless new Day-Brite "LUVEX" is ready.

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But then, add these "LUVEX" extras—sturdy, *no-sag*, heavy gauge steel chassis, *enclosure and louvers completely interlocked into a rigid one-piece unit*, quick, easy installation and smart appearance—and the "LUVEX" is absolutely *everything* you expect of Slimline lighting.

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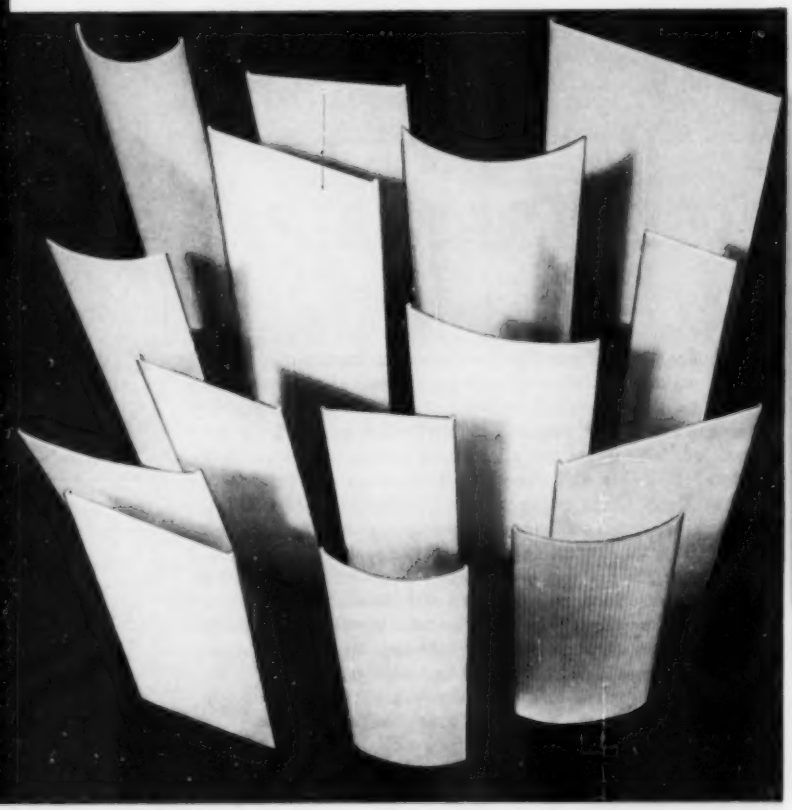

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KOPP GLASS . . .

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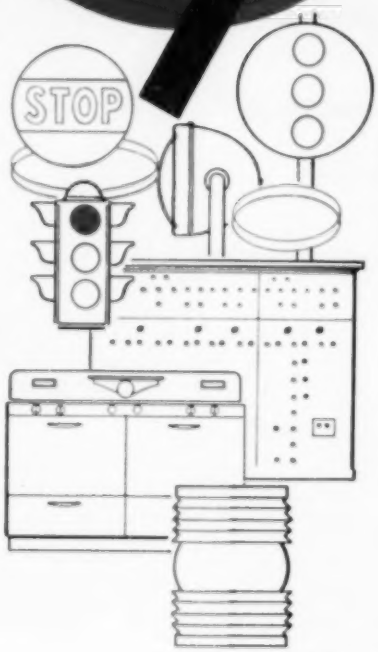

Kopp Glass products can play an important part in making light do your bidding; you can use Kopp lenses to diffuse, deflect or concentrate beams of light, to transmit colors, for infra-red or ultra-violet applications, for "on" or "off" lights, for all sorts of signals where uniform colors, durability and dimensional accuracy are important. Other Kopp Glass products are liquid-level sight glasses, transparent instrument cases, glass domes, panels for domestic oil burners, beads for glass-to-metal seals, direction signals.

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Lighting Equipment: Litecontrol No. 4044 pendant mounted fixture
Spacing: 10 foot centers
Lamps per fixture: 4–40 watt
Footcandles: 35 in service (overage)

WRITE TODAY! This new catalog is yours for the asking

Contains: Pictorial Index for easy, quick reference. Complete descriptions and specifications on all Litecontrol fixtures, including utilization factors, formulae and all data necessary to figure an installation from start to finish.

LITECONTROL
Fixtures

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1 In the new addition to the Greist Manufacturing Company of New Haven, General Electric slimline fluorescent lamps are used throughout. More than 80 footcandles of light, plus light-colored surroundings, make seeing easier—boost worker accuracy and production.

The continuous rows of G-E slimline lamps are easy to maintain; rugged push-pull sockets permit one man to quickly replace a 16-foot row of lamps without moving his ladder. And slimlines start instantly, need no starters, have long life and high efficiency.

2 4-lamp fixtures do the job throughout the plant, as in this parts tumbling room. Decision to use slimline was based on long life and low-cost maintenance.

G-E SLIMLINE FLUORESCENT

- **High efficiency**
- **Low maintenance cost**
- **Instant start, no starter needed**
- **Single-pin base, easy in and out**

3 All these advantages of General Electric slimline fluorescent lamps make them a logical choice in most stores, factories, and offices. For your next installation, use slimline fluorescent, another G-E development. General Electric lamp research works constantly to make G-E lamps *Stay Brighter Longer*.

GENERAL ELECTRIC

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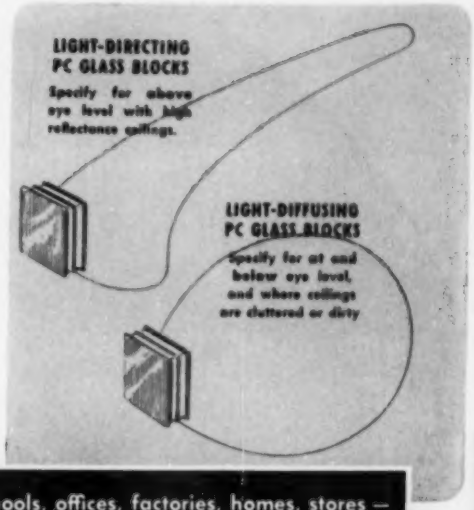
PC Functional Glass Blocks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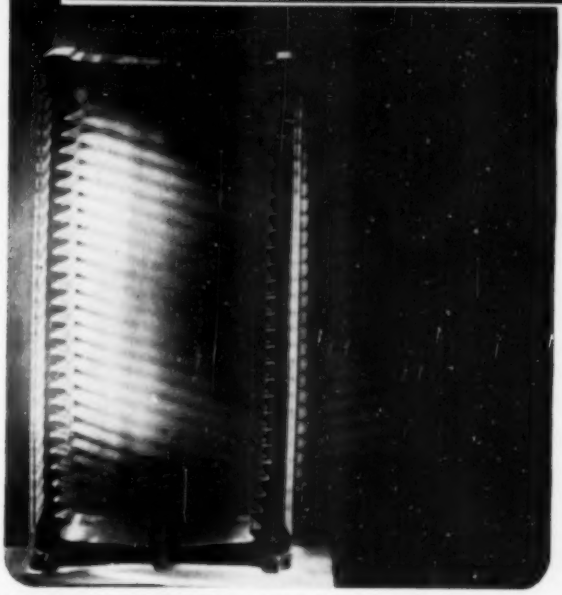
PC GLASS BLOCKS
Specify for above eye level with high reflectance ceilings.
LIGHT-DIFFUSING
PC GLASS BLOCKS
Specify for at and below eye level, and where ceilings are cluttered or dirty

. . . now completely redesigned for use in schools, offices, factories, homes, stores — in accordance with the "IES Recommended Practice for Daylighting"



UNRETOUCHED PHOTO showing typical light paths through cross-section of PC Soft-Lite Prism Light-Directing Block.

MARKING a major step forward in the science of daylighting, the new PC *Functional* Glass Blocks are another far-reaching contribution to the long list of achievements of Pittsburgh Corning Corporation over the years. For, wherever seeing is important—wherever precision tasks are performed—the built-in daylight control of PC *Functional* Glass Blocks makes it possible to admit ample quantities of daylight, even to the farthest reaches of the room, without glare and evenly diffused. These glass blocks are unexcelled in providing comfortable low-brightness ratios, high illumination levels and top quality daylighting.

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a fluorescent lighting installation
is the *Ballast*

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a good *Ballast*

. . . get a G-E *Ballast*

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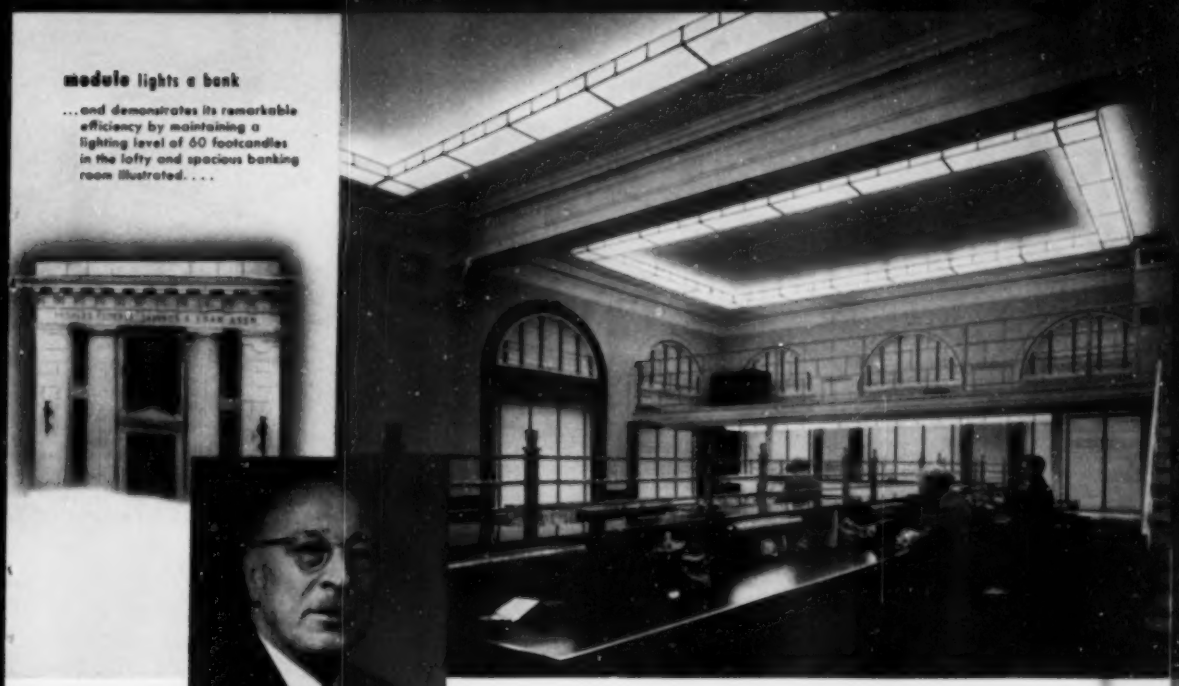
GENERAL ELECTRIC

412-83

module lights a bank

...and demonstrates its remarkable efficiency by maintaining a lighting level of 60 footcandles in the lofty and spacious banking room illustrated....



Mr. Alex Salvatori, President, Peoples Federal Savings and Loan Assn., Wheeling, West Virginia; Director Federal Home Loan Bank (Dist. No. 3) Pittsburgh; past president, West Virginia Savings and Loan League

"we wanted the very latest and finest in everything, including lighting . . . *we chose* Mitchell module"

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Mitchell MODULE delivers *20% more light*, fits *any* architectural interior, provides *custom appearance* in unlimited pattern arrangements—at no more than the cost of ordinary fixtures. For *any* commercial installation—whether it calls for one unit or a hundred—specify MODULE and deliver the greatest development in lighting since the fluorescent lamp. Write today for the full details.

these 4 low-cost modules are the "building blocks" of a perfect custom-fitting lighting installation

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C 4 40-Watt T-12 48" Type F Lamps

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modules fit together perfectly end to side, end to end, side to side... to form more than 50,000 different lighting patterns...to fit any ceiling shape or size...mixing all light sources in one harmonious system... with equal brightness throughout (no dark sides or ends)...so you can put the light where it is needed!

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PLEXIGLAS ¼" thick has seven times the impact strength of glass—yet weighs less than half as much. Light weight and shatter resistance permit its use in large sections with complete safety and ease, and economy of installation. Maintenance costs are negligible.

You'll find PLEXIGLAS wall-to-wall diffusing panels in banks, drafting rooms, stores, classrooms and control rooms—wherever *glare-free* lighting is desired, and safety with savings is essential. Tell us about *your* lighting problem. We'll be glad to send you full information regarding *modern* lighting with PLEXIGLAS.

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with economical commercially-available materials

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Please send immediately your free new booklet on "Better Classroom Daylighting."

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built like a bridge

"LIGHT BEAMS" for BUILDING FOOT-CANDLE LEVELS

This actual photograph of a pendant mounted "Monroe" Slimline Luminaire proves our point that it's "built like a bridge." The "Monroe" is not recommended for heavy foot-traffic, but its bridge-like construction provides for perfect alignment on continuous runs with hangers spaced only at every 8 feet. This minimum of hangers and the unit's rugged construction mean reduced installation costs and improved appearance.

In design, in construction, in flexibility of use—the new "Monroe" is the ideal fluorescent unit. Its efficiencies of up to 83% with 25-35° shielding; its low initial cost; its long service life add up to *good lighting at economical cost.*

"The Monroe"

96" T-12 SLIMLINE and STANDARD 40-WATT

LUMINAIRES

Framed-plastic, aluminum or steel side-panels, designed for quick and easy surface or pendant mounting, individually or in continuous row.

WRITE TODAY for complete information on the "Monroe" and other Fluorescent Luminaires in the Pittsburgh PermaReflector Presidential Series.

PITTSBURGH REFLECTOR COMPANY

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PermaReflector Lighting Engineers in All Principal Cities

PITTSBURGH PERMAREFLECTORS ARE DISTRIBUTED BY LEADING ELECTRICAL WHOLESALERS EVERYWHERE

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Architects: Graham, Anderson, Probst, White
Fixture Manufacturer: Morris Kurtzon, Inc.
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Glass: CORNING ALBA-LITE

Your most adaptable fluorescent lighting medium . . .

Corning "ALBA-LITE"

This photograph gives you an idea of how well CORNING ALBA-LITE diffuses fluorescent light . . . especially desirable for office work. The qualities of diffusion and brightness control are contained within a thin opal glass panel. This makes ALBA-LITE adaptable to almost any type of installation whether recessed or exposed.

There is no limit to the design flexibility that can be achieved with ALBA-LITE. It is obtainable flat or bent in four standard patterns as shown.

Widths vary from 2" to 24", lengths from 8" to 100". It may be used in fixtures, or glass ceilings, as required.

Bulletin LS-17 describes this versatile lighting glassware in detail and illustrates many ways it is being used. This new 30 page bulletin is yours for the asking. Use coupon below.

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Corning means research in Glass

FOR EFFICIENT, ATTRACTIVE LIGHTING . . .
CORNING ALBA-LITE for diffusion of fluorescent light . . . CORNING FOTA-LITE for high level illumination . . . CORNING brand LENS PANELS and PYREX brand LENSLITES for prismatic light control

CORNING GLASS WORKS
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Please send me a free copy of your bulletin LS-17 describing CORNING ALBA-LITE.

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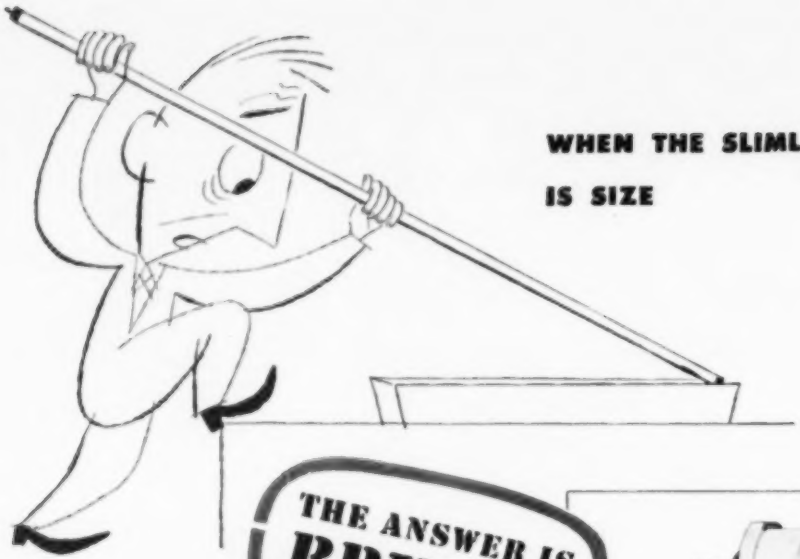

WHEN THE SLIMLINE PROBLEM IS SIZE

THE ANSWER IS BRYANT

WITH NEW BRYANT PUSH CONTACT LAMPHOLDERS FOR ALL SIZES OF SLIMLINE LAMPS

Bryant now presents a NEW line of quality Push Contact Lampholders with these important features:

UNIVERSAL—they accommodate all types of Slimline Lamps.

COMPACT—require a minimum of space.

EASY TO WIRE—1/4" lay stranding simplifies wiring (eliminates dipping or twisting of wire ends). All four devices are equipped with No. 18 stranded, 1/32" insulation, 1000 Volt, 90°C. Thermoplastic wire.

MADE OF WHITE THERMO-SETTING PLASTIC

PLUS THIS EXCLUSIVE BRYANT FEATURE...

High voltage devices Nos. 4570 and 4572 are so designed that when the lamp pin is inserted, the contact in the plunger moves back and the end of the lamp seats firmly against the spring actuated plunger, while the opposite lamp pin is being inserted in the low voltage lampholder. When the lamp is in place, the lamp ends seat against the lampholders, providing greatest possible support.

No. 4569—Butt-On Mounting, for low voltage primary 660 Watts, 250 Volts, two twelve inch white leads.

No. 4570—Butt-On Mounting, for high voltage secondary 660 Watts, 1000 Volts, one twelve inch red lead.

No. 4571—Flush Mounting with Bracket, for low voltage primary, 660 Watts, 250 Volts, two twelve inch white leads.

No. 4572—Flush Mounting with Bracket, for high voltage secondary, 660 Watts, 1000 Volts, one twelve inch red lead.

Listed as standard by Underwriters' Laboratories, Inc.

THE BRYANT ELECTRIC COMPANY
BRIDGEPORT 2, CONNECTICUT
CHICAGO • LOS ANGELES

BRYANT
SUPERIOR WIRING DEVICES

Continued from page 147

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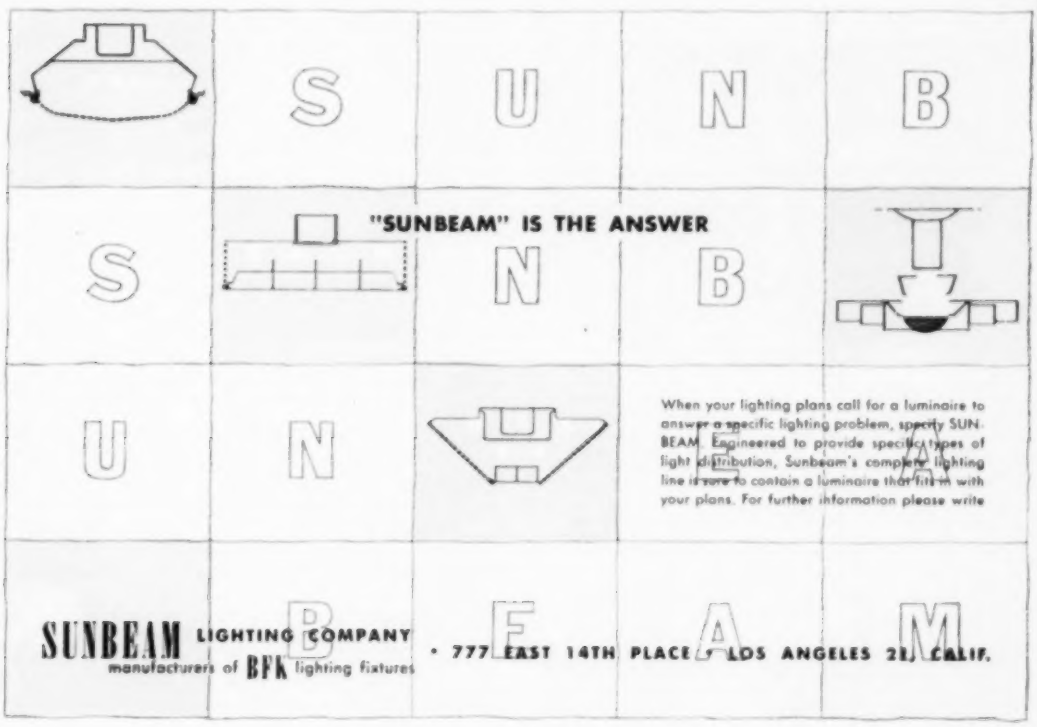
Calling on the wholesale electrical trade etc. for the past 16 years within 150 mile radius of Philadelphia selling residential, commercial and industrial lighting lines. Desires to add complete line incandescent glassware on exclusive basis. Address Box 125, Illuminating Engineering Society, Publications Office, 51 Madison Ave., New York 10, N. Y.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"SUNBEAM" IS THE ANSWER
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When your lighting plans call for a luminaire to answer a specific lighting problem, specify SUNBEAM. Engineered to provide specific types of light distribution, Sunbeam's complete lighting line is sure to contain a luminaire that fits in with your plans. For further information please write
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manufacturers of BFK lighting fixtures
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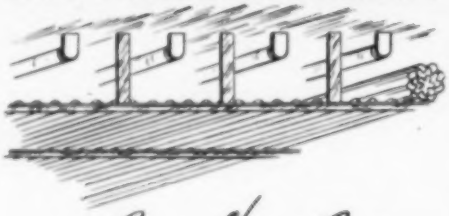

of Luminous Ceilings

Martin sheeting provides greater comfort 5 ways.

1) HIGH LEVELS OF ILLUMINATION — up to 1000 footcandles easily obtained with no discomfort.
2) LOW BRIGHTNESS — never before was such low brightness possible at any level of illumination.
3) SOFT SHADOWS—helios ratios amazingly reduced.
4) MAXIMUM UNIFORMITY — identical light intensity from wall to wall.
5) ELIMINATION OF GLARE — complete absence of reflected glare.

Free sample and price list are yours on request.

MARTIN *Electric Products, Inc.*

346 Somerville Ave. Somerville 43, Mass.

This BETTER FLUORESCENT LIGHTING PERFORMANCE IS VISIBLE TO THE EYE

It's possible to pick out Acme Electric fluorescent ballast equipped fixtures in service by noticing these important performance features. First—all lamps of multiple lamp fixtures light up at the same instant as a result of full rated watt output. Second—no flicker in operation because secondary voltage exactly complies to lamp operating voltage. Third—noise-free because cores have no loose laminations, are thoroughly impregnated and sealed in compound. These are a few of the important features of Acme Electric ballasts that assure better performance, and longer service to fluorescent lamps.

ACME ELECTRIC CORPORATION
292 Water St. Cuba, N. Y.

Acme Electric

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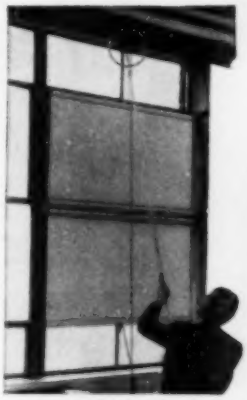
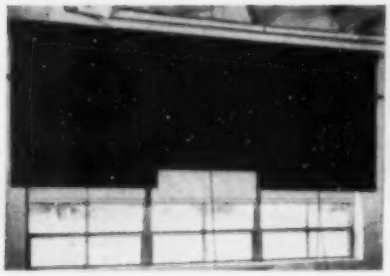
WINDOW SHADES OF SPECIAL DESIGN

for Full Range Daylighting or Darkening.



Your Building and Equipment file should contain a copy of "Specify the Line of Special Design," furnished promptly upon request.



FOR BEST LIGHT CONTROL

Use the V-DOUBLE Roller Shade provided with DE-MOUNTABLE fixtures for either wood or metal sash. (Patented)

FOR DARKENING

extremely wide or multiple sash unit windows apply the Draper X-L Window Shading Unit. (Patented)

FOR PORTABLE DARKENING

The DRAPER PAKFOLD is adapted to windows of practically any size—easily and quickly moved to various classrooms—gives excellent darkening. (Patented)

LUTHER O. DRAPER SHADE CO., Dept. MB2, SPICELAND, INDIANA

GLASS

for lighting

Dunbar, America's most versatile glass plant, offers you 38 years of glass making know-how. Complete (1) molding, (2) decorating and (3) cutting facilities all in one location provide efficient, economical production and rapid service.

Let us quote on your special shapes. Or, possibly one of our many stock blanks will save you money and time.

Write for catalogues on Dunbar "Lighting Glassware" and "Dunbar Glass Cylinders". Address Box 23

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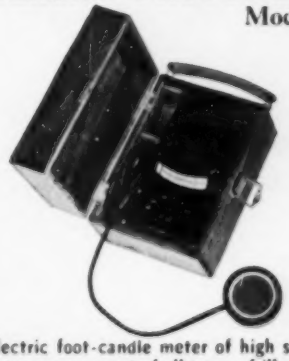
PHOTOVOLT
UNIVERSAL PHOTOMETER

Mod. 200



A photoelectric foot-candle meter of high sensitivity for accurate measurement of all types of illumination.

- 4 measuring ranges: 0-5, 0-25, 0-100, 0-500 ft.-cdl.
- Simple in operation, dependable, conveniently portable
- Available with cosine-corrected photocell search unit

Also: Mod. 210 with twin-photocell search unit and 0.005 ft.-cdl. / div. for clear registration of lowest light levels in street and highway lighting surveys.

Write for Bull. No. 200 to

PHOTOVOLT CORP.

95 Madison Ave. New York 16, N. Y.

USERS SAVE 2/3

with

Westinghouse *Fluorescent Lamps*

the lamps that last 3 times as long... yet cost no more!

Yes, one Westinghouse fluorescent lamp now lasts as long as 3. In average store installations, for example, it lasts 2½ years; in average one-shift offices or factories, 3 years. You actually buy lamps only ⅓ as often! You also *save on the time spent replacing burned-out lamps.* So, start getting these economies now. Next time specify Westinghouse fluorescent lamps. Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J.

YOU CAN BE SURE... IF IT'S Westinghouse

There is NO SUCH THING as an "RLM TYPE" Lighting Unit!

Either it is RLM CERTIFIED or it is NOT.
The Only Way To Be Sure Is To

SEE the RLM LABEL!

Looks can be deceiving in lighting units, too! A lighting unit may LOOK like an RLM Unit, it may have a similar outward appearance, contour, shielding angle, etc.—but unless it is made in accordance with RLM Standard Specifications and carries the RLM Label, it is *not* an RLM Lighting Unit. There is no such thing as an "RLM Type" that does not have the label.

Why No "RLM TYPE"? The RLM Label on fluorescent and incandescent lighting units, not only assures the buyer of design and construction that meets certain minimum standards*, but also provides him with a WARRANTY of UNIFORM QUALITY.

Only those products of lighting manufacturers which are *consistently proved* to be of *uniform quality* and meet the published specifications of the Institute are permitted to bear the RLM Label. This uniformity of quality is of exceptional importance to all those who buy, use, specify, recommend or sell lighting equipment. It is essential to uniformly satisfactory lighting equipment performance, that each unit in the system perform with equal efficiency to the other . . . that ballasts function with uniform efficiency . . . that the reflection factor be uniform from unit to unit. . . that the units be of uniformly durable construction with the identical-gauge steel and the same thickness Porcelain Enamel. Such uniformity reduces to a minimum the plague of spotty performance by individual units in a lighting system.

How RLM Checks Uniformity of Quality

According to the RLM testing and inspection procedures, representatives of the Electrical Testing Laboratories periodically visit plants of all RLM member-manufacturers. They take lighting units right off the assembly lines and out of stock for testing and inspection at their laboratories. They may also obtain test samples directly from the distributors' shelves or out of contractors' stocks in order to check Uniform Quality at every level of distribution.

This activity of the RLM Standards Institute, which makes possible the Warranty of Uniform Quality, is not duplicated by any other agency in the lighting industry. That is why there is no such thing as an "RLM Type" Lighting Unit.

FREE SPECIFICATIONS BOOKLET! This up-to-date 36-page booklet tells why it is important to SEE THE RLM LABEL before buying or specifying lighting units. It contains all RLM Specifications, covering vital construction and performance factors that should have major consideration by the buyers and specifiers. It is an indispensable help in the sale of industrial lighting units. For your complimentary copy(or copies), sent without obligation, write:

RLM Standards Institute, Suite 825, 326 West Madison St., Chicago 6, Illinois.

This Advertisement is published in the Interest of the Entire Lighting Industry by

RLM STANDARDS INSTITUTE
INCORPORATED
The Sole Body Authorized to Certify Reflector and Lighting Equipment Manufacturers

*Every RLM Unit Must Conform with Certain Minimum Standards such as these:

Porcelain Enamel Reflectors – all RLM Units must have a specified thickness of Genuine Porcelain Enamel fused to steel. This unsurpassed high-reflection, high-diffusion reflecting surface is the only commercially available finish that cannot deteriorate or corrode. Simple soap-and-water cleaning quickly restores it to original efficiency.

High-Quality Ballasts – RLM Fluorescent Units must be equipped with Certified Ballasts which prevent high-temperature ballast operations, supply proper starting current and maintain proper operating watts to the lamp. Because of their high power factor, present wiring capacity can be utilized most efficiently.

Reflector Design – every RLM Unit must conform with the most accepted principles of Illuminating Engineering. Such design protects the workers' eyes while delivering, not only the most light per dollar, but also the required quality of light for the individual seeing task.

Sound Construction – RLM Units must comply with high fabrication and materials to insure standards of maximum resistance to sag, distortion and breakage.

H-6651

SYLVANIA'S FLEXI-MODULE LUMINOUS CEILING LEADS THE WAY...

at JORDAN MARSH, Boston

most modern The handsome new Jordan Marsh Men's Store in Boston is up-to-the-minute from floor to ceiling! And that ceiling is Sylvania's Flexi-Module Luminous Ceiling, brand new and already showing the way to greater beauty and practicality in interior illumination. A pattern with a purpose!

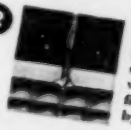
most flexible Sylvania's Flexi-Module system is simplicity itself to install and maintain. The grids may be cut to fit ceilings of any shape. Fixtures properly spaced illuminate floor area with soft diffused light . . . fixtures concentrated above the sub-ceiling provide high intensity lighting . . . spot lights can be attached to grids to accent special displays.

most economical Sylvania Flexi-Module Luminous Ceiling gives remarkable savings . . . the louvered sections screen all fixtures; thus decorative, expensive fixtures are not needed. Such installations as air-conditioning ducts, sprinkler systems, telephone and electrical wiring and other utilities need *not* be buried in concrete, but can be hung on the true ceiling. And because everything is hidden above the sub-ceiling, maintenance too is easier, less expensive. For full information call your local Sylvania office or write Sylvania Electric Products Inc., Ipswich, Mass.

ONLY 3 SIMPLE PARTS

1.

Sylvania Fluorescent Lighting Fixtures are suspended above the Flexi-Module grids . . . can be the simplest, most efficient, least expensive types.

2. 

Flexi-Module grid sections are supported by Sylvania's exclusive "star" suspension bolt. Hanger straps provide approximate adjustment, and final adjustment is made from below by screwing up on threaded bolt.

3.

Flexi-Module louver sections are lacquered, non-static aluminum grids, 32" square, light in weight and yet strongly welded. No painting—no dusting! Also available are colored grids, opaque and translucent panels, to provide a wide variety of architectural treatments.

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